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E L E M E N T S
O F
C H E M I S T R Y.

By M. I. A. CHAPTAL, .
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AT MONTPELLIER, HONORARY INSPECTOR OF THE MINES OF
FRANCE, AND MEMBER OF SEVERAL ACADEMIES OF
SCIENCES, MEDICINE, AGRICULTURE, IN-
SCRIPTIONS AND BELLES-LETTRES.

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1800.



THE great experience of M. Chaptal, his unaffected candour, and the perspicuity which is seen in every part of the following treatise, cannot but render it extensively useful. I have been particularly careful not to diminish this last merit, by deviating in any respect from that scrupulous attention to accuracy which is indispensably required to give authority to the translation of a work of science.

W. NICHOLSON.



C O N T E N T S

OF THE

FIRST VOLUME.

PART FIRST.

CONCERNING THE CHEMICAL PRINCIPLES.

INTRODUCTION.

	Page
DEFINITION of Chemistry; its Object and Means—Description of a Laboratory, and the principal Instru- ments employed in chemical Opera- tions, with a Definition of those Ope- rations	I

SECTION I.

Concerning the General Law which tends to bring the Particles of Bodies toge- ther, and to maintain them in a State of Mixture or Combination	22
	Of

vi C O N T E N T S.

Of the Affinity of Aggregation	—	—	23
Of the Affinity of Composition	—	—	25

S E C T I O N I I.

Concerning the various Means employed by Chemists to overcome the Adhesion which exists between the Particles of Bodies	—	—	—	41
--	---	---	---	----

S E C T I O N I I I.

Concerning the Method of Proceeding which the Chemist ought to follow in the Study of the various Bodies pre- sented to us by Nature	—	—	—	48
---	---	---	---	----

S E C T I O N I V.

Concerning Simple or Elementary Sub- stances	—	—	—	60
CHAP. I. Concerning Fire	—	—	—	62
ART. I. Concerning Caloric and Heat	—	—	—	64
ART. II. Concerning Light	—	—	—	83
CHAP. II. Concerning Sulphur	—	—	—	88
CHAP. III. Concerning Carbone	—	—	—	95

S E C T I O N V.

Concerning Gases, or the Solution of cer- tain Principles in Caloric, at the Tem- perature of the Atmosphere	—	—	—	97
CHAP. I. Concerning Hydrogenous Gas, or In- flammable Air	—	—	—	102
				CHAP.

C O N T E N T S.		vii
CHAP. II.	Concerning Oxygenous Gas, or Vital Air	113
CHAP. III.	Concerning Nitrogen Gas, Azote, or Atmospheric Mephitic	138

SECTION VI.

Concerning the Mixture of Nitrogen and Oxygen Gas; or of Atmospheric Air	141
--	-----

SECTION VII.

Concerning the Combination of Oxygenous Gas and Hydrogen, which forms Water	145
ART. I. Concerning Water in the State of Ice	148
ART. II. Concerning Water in the Liquid State	152
ART. III. Concerning Water in the State of Gas	156

SECTION VIII.

Concerning the Combinations of Nitrogen Gas.	
1. With Hydrogen Gas.	
2. With Earthy Principles forming the Alkalis	165
CHAP. I. Concerning Fixed Alkalis	166
ART. I. Concerning the Vegetable Alkali, or Potash	167
ART. II. Concerning the Mineral Alkali, or Soda	170
CHAP. II. Concerning Ammoniac, or the Volatile Alkali	178
SEC.	

SECTION IX.

Concerning the Combination of Oxigene
with certain Bases forming Acids — 184

CHAP. I. Concerning the Carbonic Acid	—	190
ART. I. Carbonate of Potash	—	201
ART. II. Carbonate of Soda	— —	202
ART. III. Carbonate of Ammoniac	—	203
CHAP. II. Concerning the Sulphuric Acid	—	205
ART. I. Sulphate of Potash	— —	212
ART. II. Sulphate of Soda	— —	213
ART. III. Sulphate of Ammoniac	—	215
CHAP. III. Concerning the Nitric Acid	—	217
ART. I. Nitrate of Potash	— —	228
ART. II. Nitrate of Soda	— —	236
ART. III. Nitrate of Ammoniac	—	<i>ib.</i>
CHAP. IV. Concerning the Muriatic Acid	—	237
ART. I. Muriate of Potash	— —	249
ART. II. Muriate of Soda	— —	250
ART. III. Muriate of Ammoniac	—	256
CHAP. V. Concerning the Nitro-muriatic Acid		260
CHAP. VI. Concerning the Acid of Borax	—	263
ART. I. Borate of Potash	— —	267
ART. II. Borate of Soda	— —	268
ART. III. Borate of Ammoniac	— —	273
Concerning Mineral Waters	— —	274

ADVERTISEMENT

OF

THE AUTHOR.

AGRICULTURE is no doubt the basis of public welfare, because it alone supplies all the wants which nature has connected with our existence. But the arts and commerce form the glory, the ornament, and the riches of every polished nation ; since our refinement, and mutual dependence on each other, have created a new set of wants which require to be supplied. The cultivation of the arts is therefore become almost as necessary as that of the ground ; and the true means of securing

VOL. I.

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these two foundations of the reputation and prosperity of a state, consist in encouraging the Science of Chemistry, which discovers their principles. If this truth were not universally acknowledged, I might on the present occasion give an account of the success with which my labours have been attended in this province*. I might even call upon the public voice; and it would declare that, since the establishment of lectures on chemistry, between three and four hundred persons have every year derived advantage from instructions in this science. It is well known that our ancient schools of medicine and surgery, whose success and splendour are connected with the general interest of this province, are more flourishing and more numerous since that period. And with the same confidence I might appeal to the Public, that our manufactures are daily increasing in perfection; that several new kinds of industry have been introduced into Languedoc; that, in a regular succession, abuses have been reformed in the manufactories, while the processes of the arts

* Languedoc.

have

have been simplified; that the number of coal-mines actually wrought is increased; and that, upon my principles, and in consequence of my care and attention, manufactories of alum, of oil of vitriol, of copperas, of brown red, of artificial pozzolana, of ceruse, of white lead, and others, have been established in several parts of the province.

Chemistry is therefore essentially connected with the reputation and prosperity of a state; and at this peculiar instant, when the minds of men are universally busied in securing the public welfare, every citizen is accountable to his country for all the good which his peculiar situation permits him to do. Every one ought to hasten, and present to society the tribute of those talents which heaven has bestowed on him; and there is no one who is not able to bring some materials, and deposit them at the foot of the superb edifice which the virtuous administrators are raising for the welfare of the whole. It is with these views that I have presumed to offer to my countrymen the work which I at present publish;

lish; and I entreat them to exercise their severity upon the intention of the author only, but to reserve all their indulgence to the work.

I publish these Elements of Chemistry with the greater confidence, because I have had opportunities myself of observing the numerous applications of the principles which constitute its basis to the phenomena of nature and art. The immense establishment of chemical products which I have formed at Montpellier has allowed me to pursue the development of this doctrine, and to observe its agreement with all the facts which the various operations present to us. It is this doctrine alone which has led me to simplify most of the processes, to bring some of them to perfection, and to rectify all my ideas. It is therefore with the most intimate confidence that I propose it. I find no difficulty in making a public acknowledgment that I have for some time taught a different doctrine from that which I at present offer. I then believed it to be true and solid; but I did not on that account cease to consult nature.

nature. I have constantly entered into this research with a mind eager for improvement. Natural truths were capable of fixing themselves with all their purity in my mind, because I had banished prejudice; and insensibly I found myself drawn by the force of facts to the doctrine I now teach. Let other principles impress the same conviction on my mind; let the same number of phenomena and facts exhibit themselves in their favour; the same number of happy applications to the operations of nature and of art; let them appear to my mind with all the sacred characters of truth; and I will publish them with the same zeal, and with the same interest. I condemn equally the man who, attached to the ancient notions, respects them so much as to reject without mature examination every thing which appears to oppose them; and him who embraces with enthusiasm, and almost without reflection, the principles of any new doctrine. Both are worthy of compassion if they grow old in their prejudices; and both are worthy of blame if they perpetuate them.

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I have been careful to banish all discussions from my work. That spirit of party which but too often causes a division between persons who are pursuing the same objects, that tone of bitterness which predominates in certain disputes, that want of candour which is insensibly produced by the movements of self-love, have but too long retarded the progress of our knowledge. The love of truth is the only passion which a philosopher ought to indulge. The same object, the same interest, tend to unite chemists. Let the same spirit inspire them, and direct all their labours. Then we shall soon behold chemistry advancing in a rapid progress; and its cultivators will be honoured with the suffrage and the gratitude of their countrymen.

I have endeavoured in this work to explain my ideas with clearness, precision, and method. I know by experience that the success of any work, and its various degrees of utility, often depend on the form under which the doctrine which it contains is displayed; and it has accordingly been my intention to spare no pains
in

in exhibiting the truths which form the basis of this work in all the characters they are justly entitled to.

In composing these Elements of Chemistry, I have availed myself with advantage of all the facts which I have found in the works of the celebrated chemists who adorn this age. I have even made no scruple to follow their method in drawing up certain articles; and have transferred into my own work, almost without alteration, those facts which I have elsewhere found described with a greater degree of precision and perspicuity than I might have been capable of bestowing on them. This proceeding, in my opinion, renders homage to authors, instead of robbing them. If such a proceeding might justify reclamations, Messrs. Lavoisier, De Morveau, Berthollett, De Fourcroy, Sage, Kirwan, &c. might easily declare against me.

I was well aware that the pretension of knowing, discussing, and methodically distributing the whole of our present science of chemistry, was an enterprise beyond my ability.

ability. This science has made so great a progress, and its applications are so multiplied, that it is impossible to attend to the whole with the same care: and it appears to me that the writer of an elementary work ought at present to attend principally to the development of general principles, and content himself in pointing out the consequences, and their applications. In this way of proceeding we shall follow the method which has long been practised in the study of the mathematics; the principles of which, nearly insulated, and separated from all application, form the first study of him who means to acquire them.

To obtain a thorough acquaintance with all the knowledge which has been acquired in chemistry until our time, the chemical part of the *Encyclopédie Méthodique* may be consulted. In this work, the celebrated author gives the most interesting account of the progress of the science. Here it is that he discusses the several opinions with that candour and energy which become the man of letters whose mind is directed to truth only.

Here

Here it is that he has made a precious deposit of all the knowledge yet acquired, in order to present to us in the same point of view all which has been done, and all which remains to be done; and here, in a word, it is that Mr. De Morveau has rendered the most striking homage to the truth of the doctrine we now teach; because, after having combated some of its principles in the first volume, he has had the courage to recant, the moment the facts seen in a better point of view, and repeated experiments, had sufficiently enlightened him. This great example of courage and candour is doubtless honourable to the learned man who gives it; but it cannot fail to add still more to the confidence which may be placed in the doctrine which is its object.

The development of the principles upon which the New Nomenclature is established, may be found in the Elementary Treatise of Chemistry of Mr. Lavoisier; and I refer likewise to this excellent work for the figure and explanation of all the apparatus I shall have occasion to speak of.

x. *Advertisement of the Author.*

of. I take this step the more earnestly, because, by associating my own productions to those of this celebrated chemist, I entertain the hope of securing their success, and can deliver them into the hands of the public with greater confidence.

PRE-

PRELIMINARY DISCOURSE.

IT appears that the ancient nations possessed some notions of chemistry. The art of working metals, which dates from the most remote antiquity; the lustre which the Phœnicians gave to certain colours; the luxury of Tyre; the numerous manufactures which that opulent city included within its walls—all announce a degree of perfection in the arts, and suppose a considerable extent and variety of chemical knowledge. But the principles of this science were not then united into a body of doctrine; they were concentrated in the workshops of the manufacturers, where they had their origin; and observations alone, transmitted from one operator to another,

another, enlightened and conducted the steps of the artist. Such, no doubt, has been the origin of all the sciences. At first they presented unconnected facts ; truths were confounded with error ; time and genius alone could clear up the confusion ; and the progress of information is always the fruit of slow and painful experiment. It is difficult to point out the precise epocha of the origin of chemical science ; but we find traces of its existence in the most remote ages. Agriculture, mineralogy, and all the arts which are indebted to it for their principles, were cultivated and enlightened. We behold the original nations, immediately succeeding the fabulous ages, surrounded by all the arts which supplied their wants ; and we may compare chemistry to that famous river whose waters fertilize the lands they inundate, but whose sources are still to us unknown.

Egypt, which appears to have been the nurse of chemistry reduced to principles, was not slow in turning the applications of this science towards a chimerical end. The first seeds of chemistry were soon changed
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by the passion of making gold. In a moment all the labours of operators were directed towards alchemy alone; the great object of study became fixed on an endeavour to interpret fables, allusions, hieroglyphics, &c.; and the industry of several centuries was consecrated to the enquiry after the philosopher's stone. But though we admit that the alchemists have retarded the progress of chemistry, we are very far from being disposed to any outrage on the memory of these philosophers: we allow them the tribute of esteem to which on so many accounts they are entitled. The purity of their sentiments, the simplicity of their manners, their submission to Providence, and their love for the Creator, penetrate with veneration all those who read their works. The profoundest views of genius are every where seen in their writings, allied with the most extravagant ideas. The most sublime truths are degraded by applications of the most ridiculous nature; and this astonishing contrast of superstition and philosophy, of light and darkness, compels us to admire them, even at the instant that

that we cannot withhold our censure. We must not confound the sect of alchemists, of whom we shall proceed to speak, with that crowd of impostors, that sordid multitude of operators at the furnace, whose researches were directed to the discovery of minds capable of being imposed on, who fed the ambition of such weak minds by the deceitful hope of increasing their riches. This last class of vile and ignorant men has never been acknowledged by the true alchemists; and they are no more entitled to that name, than the vender of specifics on the stage to the honourable name of Physician.

The hope of the alchemist may indeed be founded on a slender basis ; but the great man, the man of genius, even at the time when he is pursuing an imaginary object, knows how to profit by the phenomena which may present themselves, and derives from his labours many useful truths which would have escaped the penetration of ordinary men. Thus it is that the alchemists have successively enriched pharmacy and the arts with most of their compositions. The strong desire of acquiring riches has in
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all times been a passion so general, that this single motive has been sufficient to lead many persons to the cultivation of a science which has more relation than any other to metals; which studies their nature more particularly, and appears to facilitate the means of composing them. It is known that the Abdarites did not begin to consider the sciences as an occupation worthy a reasonable man, until they had seen a celebrated philosopher enrich himself by speculations of commerce; and I do not doubt but that the desire of making gold has decided the vocation of several chemists. We are therefore indebted to alchemy for several truths, and for several chemical professors: but this obligation is small, in comparison to the mass of useful truth which might have been afforded during the course of several centuries; if, instead of endeavouring to form the metals, the operations of chemists had been confined to analysing them, simplifying the means of extracting them, combining them together, working them, and multiplying and rectifying their uses.

The rage for making gold was succeeded
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by the seductive hope of prolonging life by means of chemistry. The persuasion was easily admitted, that a science which affords remedies for all disorders, might without effort succeed in affording a universal medicine. The relations which have been handed down to us of the long life of the ancients, appeared to be a natural effect of their knowledge in chemistry. The numerous fables of antiquity obtained the favour of being admitted among established facts; and the alchemists, after having exhausted themselves in the search after the philosopher's stone, appeared to redouble their efforts to arrive at an object still more chimerical. At this period the elixirs of life, the arcana, the polychrest medicines, had their origin; together with all those monstrous preparations, of which a few have been handed down even to our days.

The chimera of the universal medicine agitated the minds of most men in the sixteenth century; and immortality was then promised with the same effrontery as a Charlatan now announces his remedy for every disease. The people are easily seduced by
these

these ridiculous promises; but the man of knowledge can never be led to think that chemistry can succeed in reversing that general law of nature which condemns all living beings to renovation, and a continual circulation of decompositions and successive generations. This sect gradually became an object of contempt. The enthusiast Paracelsus, who, after having flattered himself with immortality, died at the age of forty-eight at an inn at Saltzburg, completed its disgrace. From that moment the scattered remains of this sect united themselves, never more to appear again in public. The light which began to shine forth on all sides, rendered it necessary that they should have recourse to secrecy and obscurity; and thus at length chemistry became purified.

James Barner, Bohnius, Tachenius, Kunckel, Boyle, Crollius, Glafer, Glauber, Schroder, &c. appeared on the ruins of these two sects, to examine this indigested aggregate, and separate from the confused mass of phenomena, of truth and of error, every thing which could tend to enlighten the science. The sect of the adepts, urged on

by the madness of immortality, had discovered many remedies ; and pharmacy and the arts then became enriched with formulæ and compositions, whose operations required only to be rectified, and their applications better estimated.

Nearly at the same time appeared the celebrated Becher. He withdrew chemistry from the too narrow limits of pharmacy. He shewed its connection with all the phenomena of nature ; and the theory of the formation of metals, the phenomena of fermentation, the laws of putrefaction, were all comprehended and developed by this superior genius. Chemistry was then directed to its true object : and Stahl, who succeeded Becher, reduced to certain general principles all the facts with which his predecessor had enriched the science. He spoke a language less enigmatical ; he classed all the facts with order and method ; and purged the science of that alchemic infection, to which Becher himself was too much attached. But if we consider how great are the claims of Stahl, and how few the additions which have been made to his doctrine

trine until the middle of this century, we cannot but be astonished at the small progress of the science. When we consult the labours of the chemists who have appeared since the time of Stahl, we see most of them chained down to the steps of this great man, blindly subscribing to all his ideas; and the labour of thinking appeared no longer to exist among them. Whenever a well-made experiment threw a gleam of light unfavourable to his doctrine, we see them torment themselves in a ridiculous manner to form a delusive interpretation. Thus it was that the increase of weight which metals acquire by calcination, though little favourable to the idea of the subtraction of a principle without any other addition, was nevertheless incapable of injuring this doctrine.

The almost religious opinion which enslaved all the chemists to Stahl, has no doubt been pernicious to the progress of chemistry. But the strong desire of reducing every thing to first principles, and of establishing a theory upon incomplete experiments, or facts imperfectly seen, did not admit of the smallest obstacles. From the

moment that analysis had shewn some of the principles of bodies, the chemist thought himself in possession of the first agents of nature. He considered himself as authorized to regard those bodies as elements which appeared no longer susceptible of being decomposed. The acids and the alkalis performed the principal part in natural operations : and it appeared to be a truth buried in oblivion, that the term where the artist stops is not the point at which the Creator has limited his power ; and that the last result of analysis does indeed mark the limits of art, but does not fix those of nature. We might likewise reproach certain chemists for having too long neglected the operations of the living systems. They confined themselves in their laboratories, studied no bodies but in their lifeless state, and were incapable of acquiring any knowledge but such as was very incomplete : for he who, in his researches, has no other object in view than that of ascertaining the principles of a substance, acts like a physician who should suppose he had acquired a complete notion of the human body by
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confining his studies to the dead carcase. But we must likewise observe that, in order to form a proper notion of the phenomena of living bodies, it is necessary to possess the means of confining the gaseous principles which escape from bodies ; and of analysing these volatile and invisible substances which combine together. Now this work was impossible at that time ; and we ought to beware of imputing to men those errors which arise from the state of the times in which they lived.

It may perhaps be demanded, on this occasion, why chemistry was sooner known, and more generally cultivated, in Germany and in the North than in our kingdom. I think that many reasons may be given for this. In the first place, the scholars of Stahl and of Becher must have been more numerous, and consequently their instruction farther extended. Secondly, the working of mines having become a resource necessary to the governments of the North, has been singularly encouraged ; and that chemistry which enlightens mineralogy must necessarily

family have participated in its encouragements *.

The study of chemistry did not begin to be cultivated to advantage in France until the end of the last century. The first wars of Louis XIV. so proper to develop the talents of the artist, the historian, and the military man; appeared little favourable to

* Since the French government has facilitated the study of mineralogy by the most superb establishments, we have beheld the taste for chemistry revive, the arts which have the working of metals for their object have been rendered more perfect, and the mines which have been wrought are more numerous. Mr. Sage has been more particularly assiduous and zealous to turn the favour of government towards this object. I have been a witness to the laborious attention of this chemist to effect this revolution. I have beheld the personal sacrifices he made to bring it forward. I have applauded his zeal, his motives, and his talents. The same sentiments still occupy my mind; and though I teach a doctrine at present which is different from his, this circumstance arises from the impossibility of commanding opinions. The philosopher who is truly worthy of this name, is capable of distinguishing the friend of his art from the slave of his system: and, in a word, every one ought to write according to his conviction; the most sacred axiom of the sciences being, "*Amicus Plato, sed magis amica veritas.*"

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the peaceable study of nature. The naturalist who in his researches sees union and harmony around him, cannot be an indifferent spectator of the continual scenes of disorder and destruction; and his genius is crushed in the midst of troubles and agitations. The mind of the great Colbert, deeply penetrated with these truths, quickly endeavoured to temper the fire of discord, by turning the minds of men towards the only objects which could secure the peace and prosperity of the state. He exerted himself to render trade flourishing: he established manufactories: learned men were invited from all parts, encouraged, and united together, to promote his vast projects. Then it was that the ardour of enquiry replaced for a time the fury of conquest; and France very soon stood in competition with all nations for the rapid progress of the sciences, and the perfection of the arts. Lemery, Homberg, and Geoffroy arose nearly at the same time; and other nations were no longer entitled to reproach us for the want of chemists. From that moment the existence of the arts appeared to be well assured. All the

the sciences which afford their first principles, were cultivated with the greatest success: and it will scarcely be credited that, in the space of a few years, the arts were drawn from a state of non-entity; and carried to such a degree of perfection, that France; which had before received everything from foreign countries, became in possession of the glory of supplying its neighbours with models and with merchandizes.

Chemistry and natural history, however, at the beginning of this century, were cultivated only by a very small number of persons; and it was then thought that the study of these sciences ought to be confined to the academies. But two men, whose names will be ever famous, have rendered the taste general under the reign of Louis XV. The one possessed that noble spirit which is a stranger to the power of prejudice, that indefatigable ardour which so easily overcomes every obstacle, that openness of character which inspires confidence, and transfused into the minds of his pupils that enthusiasm of which he himself felt the force. While Rouelle enlightened the science of chemistry,

chemistry, Buffon prepared a revolution still more astonishing in natural history. The naturalists of the North had succeeded in causing their productions to be read by a small number of the learned; but the works of the French naturalist were soon, like those of nature, in the hands of the whole world. He possessed the art of diffusing through his writings that lively interest, that enchanting colouring, and that delicate and vigorous touch, which influence, attach, and subdue the mind. The profundity of his reasoning is every where united to all that agreeable illusion which the most brilliant imagination can furnish. The sacred fire of genius animates all his productions; his systems constantly exhibit the most sublime prospects in their totality, and the most perfect correspondence in their minute parts; and, even when he exhibits mere hypotheses, we are inclined to persuade ourselves that they are established truths. We become like the artist who, after having admired a beautiful statue, used his efforts to persuade himself that it respired, and removed every thing which could

could dissipate his illusion. We take up his work with a pleasure resembling that of the man who turns again to sleep, in hopes of prolonging the deception of an agreeable dream.

These two celebrated men, by diffusing the taste for chemistry and natural history, by making their relations and uses better known, conciliated the favour of government towards them; and from that moment every one interested himself in the progress of both sciences. Those persons who were best qualified in the kingdom, hastened to promote the revolution which was preparing. The sciences soon inscribed in their list of cultivators the beloved and respected names of La Rochefoucault, Ayen, Chaulnes, Lauraguais, Malesherve, &c.; and these men, distinguished by their birth, were honoured with a new species of glory, which is independent of chance or prejudice. They enriched chemistry with their discoveries, and associated their names with all the other literati who pursued the same career. They revived in the mind of the chemist that passion for glory, and that
ardour

ardour for the public good, which continually excite new efforts. The man of ambition and intrigue no longer endeavoured to depress the modest and timid man of genius. The credit of men in place served as a defence and support against calumny and persecution. Recompenses were assigned to merit. Learned men were dispatched into all parts of the world, to study the arts, and collect their productions. Men of the first merit were invited to instruct us with regard to our own proper riches; and establishments of chemistry which were made in the principal towns of the kingdom, diffused the taste for this science, and fixed among us those arts which we might in vain have attempted to naturalize, if a firm basis had not been first laid. The professors established in the capital, and in the provinces, appeared to be placed between the academies and the people, to prepare the latter for those truths which flow from such respectable associations. We may consider them as a medium which refracts and modifies the rays of light that issue from those various luminous centres; and directs them
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towards the manufactories, to enlighten and improve their practice. Without these favours, without this consideration and these recompenses, could it have been expected that the most unassuming among philosophers would have exerted himself to promote the reputation of a people to whom he was unknown? Could a man so situated reasonably hope to succeed in carrying a discovery into effect? Is it probable that he should have possessed a sufficient fortune to work in the large way, and by this means alone to overcome the numberless prejudices which banish men of science from manufactories? The contemplative sciences demand of the sovereign repose and liberty only; but experimental sciences demand more, for they require assistance and encouragement. What indeed could be hoped in those barbarous ages, wherein the chemist scarcely durst avow the nature of the occupation which in secret constituted his greatest pleasure? The title of Chemist was almost a reproach: and the prejudice which confounded the professors of this science with such wretched

ed projectors as are entitled only to pity, has probably kept back the revival of the arts for several centuries; for chemistry alone can afford them a proper basis. If the princes of past times had been friends of the arts, and jealous to acquire a pure and durable reputation; if they had been careful to honour the learned, to collect their valuable labours, and to transmit to us without alteration the precious annals of human genius; we should have been dispensed from labouring among the rubbish of early times, to consult a few of those remains which have escaped the general wreck; and we should have been spared the regret of allowing, after many useful researches, that the master-pieces of antiquity which remain answer scarcely any other purpose than to give us an idea of that superiority to which the earlier nations had arrived. Time, the sword, fire, and prejudice have devoured all; and our researches serve only to add to our regret for the losses which the world has sustained.

The science of chemistry possesses the glory, in our days, not only of having obtained

tained the protection of government, but it may likewise boast of another equally elevated. This science has fixed the attention, and formed the occupation, of various men in whom the habit of a profound study of the accurate sciences had produced a necessity of admitting nothing but what is proved, and of attaching themselves only to such branches of knowledge as are susceptible of strict proof. Messrs. De la Grange, Condorcet, Vander Monde, Monge, De la Place, Meusnier, Cousin, the most celebrated mathematicians of Europe, are all interested in the progress of this science, and most of them daily add to its progress by their discoveries.

So great a mass of instruction, and such ample encouragement, could not but effect a revolution in the science itself; and we are indebted to the combined efforts of all these learned men for the discovery of several metals, the creation of various useful arts, the knowledge of a number of advantageous processes, the working of several mines, the analysis of the gases, the decomposition of water, the theory of heat,
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the doctrine of combustion; and a mass of knowledge so absolute and so extended, respecting all the phenomena of art and of nature, that in a very short time chemistry has become a science entirely new. We might now say with much more truth what the celebrated Bacon affirmed of the chemistry of his time: "A new philosophy," says he, "has issued from the furnaces of the chemists, which has confounded all the reasonings of the ancients."

But while discoveries became infinitely multiplied in chemistry, the necessity of remedying the confusion which had so long prevailed, was soon seen, and indicated the want of a reform in the language of this science. There is so intimate a relation between words and facts, that the revolution which takes place in the principles of a science ought to be attended with a similar revolution in its language: and it is no more possible to preserve a vicious nomenclature with a science which becomes enlightened, extended, and simplified, than to polish, civilize, and instruct uninformed man without making any change in his natural

tural language. Every chemist who wrote on any subject was struck with the inaccuracy of the words in common use, and considered himself as authorized to introduce some change; insomuch that the chemical language became insensibly longer, more confused, and more unpleasant. Thus the carbonic acid has been known, during the course of a few years, under the names of Fixed Air, Aerial Acid, Mephitic Acid, Cretaceous Acid, &c.; and our posterity may hereafter dispute whether these various denominations were not applied to different substances. The time was therefore come in which it was necessary to reform the language of chemistry: the imperfections of the ancient nomenclature, and the discovery of many new substances, rendered this revolution indispensable. But it was necessary to defend this revolution from the caprice and fancy of a few individuals; it was necessary to establish this new language upon invariable principles; and the only means of insuring this purpose was doubtless that of erecting a tribunal in which chemists of acknowledged merit should

should discuss the words received without prejudice and without interest; in which the principles of a new nomenclature might be established and purified by the severest logic: and in which the language should be so well identified with the science, the word so well applied to the fact, that the knowledge of the one should lead to the knowledge of the other. This was executed in 1788 by Messrs. De Morveau, Lavoisier, Berthollet, and De Fourcroy.

In order to establish a system of nomenclature, bodies must be considered in two different points of view, and distributed into two classes; namely, the class of simple substances reputed to be elementary, and the class of combined substances.

1. The most natural and suitable denominations which can be assigned to simple substances, must be deduced from a principal and characteristic property of the substance intended to be expressed. They may likewise be distinguished by words which do not present any precise idea to the mind. Most of the received names are established on this last principle, such as the names

VOL. I.

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Sulphur, Phosphorus, which do not convey any signification in our language, and produce in our minds determinate ideas only, because usage has applied them to known substances. These words, rendered sacred by use, ought to be preserved in a new nomenclature; and no change ought to be made, excepting when it is proposed to rectify vicious denominations. In this case the authors of the *New Nomenclature* have thought it proper to deduce the denomination from the principal characteristic property of the substance. Thus, pure air might have been called *Vital Air*, *Fire Air*, or *Oxygenous Gas*; because it is the basis of acids, and the aliment of respiration and combustion. But it appears to me that this principle has been in a small degree departed from when the name of *Azotic Gas* was given to the atmospherical mephitic. Because, none of the known gaseous substances excepting vital air being proper for respiration, the word *Azote* agrees with every one of them except one; and consequently this denomination is not founded upon an exclusive property, distinctive and

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characteristic of the gas itself. 2. This denomination being once introduced, the nitric acid ought to have been called Azotic Acid, and its combinations Azotates; because the acids are proposed to be denoted by the name which belongs to their radical. 3. If the denomination of Azotic Gas does not agree with this æriform substance, the name of Azote agrees still less with the concrete and fixed substance; for in this state all the gases are essentially azotes. It appears to me therefore that the denomination of Azotic Gas is not established according to the principles which have been adopted; and that the names given to the several substances of which this gas constitutes one of the elements, are equally removed from the principles of the Nomenclature. In order to correct the Nomenclature on this head, nothing more is necessary than to substitute to this word a denomination which is derived from the general system made use of; and I have presumed to propose that of Nitrogene Gas. In the first place, it is deduced from the characteristic and exclusive property of

this gas, which forms the radical of the nitric acid. By this means we shall preserve to the combinations of this substance the received denominations, such as those of the Nitric Acid, Nitrates, Nitrites, &c. In this manner the word which is afforded by the principles adopted by the celebrated authors of the Nomenclature, causes every thing to return into the order proposed to be established.

2. The method made use of to ascertain the denominations suitable to compound substances, appears to me to be simple and accurate. It has been thought that the language of this part of science ought to present the analyses; that the words should be only the expression of facts; and that consequently the denomination applied by a chemist to any substance which has been analysed, ought to render him acquainted with its constituent parts. By following this method, the Nomenclature is as it were united, and identified with the science; and facts and words agree together. Two things are therefore united, which until this time appeared to have no mutual relation,

lation, the word, and the substance which it represented; and by this means the study of chemistry is simplified. But when we apply these incontestable principles to the various objects of chemistry, we ought to follow the analysis step by step, and upon this ground alone establish general and individual denominations. We ought to observe, that it is from this analytical method that the various denominations have been assigned, and that the methodical distributions of natural history have been at all times made. If man were to open his eyes for the first time upon the various beings which people or compose this globe, he would establish their relation upon the comparison of their most evident properties, and no doubt would found his first divisions upon the most sensible differences. The various modes of existence, or their several degrees of consistence, would form his first division; and he would arrange them under the heads of solid, liquid, or æriform bodies. A more profound examination, and a more connected analysis of the individuals, would soon convince him that the substances

stances which certain general relations had induced him to unite in the same class, under a generic denomination, differed very essentially among each other, and that these differences necessarily required subdivisions. Hence he would divide his solid bodies into stones, metals, vegetable substances, animal substances, &c. ; his liquids would be divided into water, vital air, inflammable air, mephitic air, &c. When he proceeded to carry his researches on the nature of these substances still farther, he would perceive that most of the individuals were formed by the union of simple principles ; and here it is that his applications of the system to be followed, in assigning a suitable denomination to each substance, would begin. To answer this purpose, the authors of the New Nomenclature have endeavoured to exhibit denominations which may point out the constituent principles. This admirable plan has been carried into execution as far as relates to substances which are not very complicated, such as the combinations of the principles with each other ; the acids, earths, metals, alkalis, &c. And
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this part of the Nomenclature appears to me to leave nothing more to be desired. The explanation may be seen in the work published on this subject by the authors, and in the Elementary Treatise of Chemistry of Mr. Lavoisier. I shall therefore do nothing more in this place than present a sketch of the method I have followed; taking for example the combinations of acids, which form the most numerous class of compounds.

The first step consisted in comprehending under a general denomination the combination of an acid with any given basis; and in order to observe a more exact arrangement, and at the same time to assist the memory, one common termination has been given to all words which denote the combination of an acid. Hence the words Sulphates, Nitrates, Muriates, are used to denote combinations of the sulphuric, nitric, and muriatic acids. The kind of combination is denoted by adding to the generic word the name of the body which is combined with the acid; thus, the sulphate of pot-ash expresses the combination

bination of the sulphuric acid with potash.

The modifications of these same acids, dependent on the proportions of their constituent principles, form salts different from those we have just spoken of; and the authors of the New Nomenclature have expressed the modifications of the acids by the termination of the generic word. The difference in the acids arises almost always from the greater or less abundance of oxigene. In the first case, the acid assumes the epithet of Oxigenated; hence the oxigenated muriatic acid, the oxigenated sulphuric acid, &c. In the second case, the termination of the word which denotes the acid, ends in *ous*; hence the sulphureous acid, the nitrous acid, &c. The combinations of these last form sulphites, nitrites, &c.; the combinations of the former compose oxigenated muriates, oxigenated sulphates, &c.

The combinations of the various bodies which compose this globe are not all as simple as those here mentioned; and it may be immediately perceived how long and trouble-

troublesome the denominations would be, if attempts were made to bestow, a single denomination which should denote the constituent principles of a body formed by the union of five or six principles. In this case, the preference has been given to the received appellation, and no other changes have been admitted but such as were necessary in order to substitute proper appellations instead of those which afforded notions contrary to the nature of the objects they were applied to.

I have adopted this Nomenclature in my lectures, and in my writings ; and I have not failed to perceive how very advantageous it is to the teacher, how much it relieves the memory, how greatly it tends to produce a taste for chemistry, and with what facility and precision the ideas and principles concerning the nature of bodies fix themselves in the minds of the auditors. But I have been careful to insert the technical terms used in the arts, or received in society, together with these two denominations. I am of opinion that, as it is impossible to change the language of the people,
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it is necessary to descend to them, and by that means render them partakers of our discoveries. We see, for example, that the artist is acquainted with the sulphuric acid by no other name than that of Oil of Vitriol, though the name of the Vitriolic Acid has been the language of chemists for a century past. We cannot hope to be more happy in this respect than our predecessors; and, so far from separating ourselves from the artist by a peculiar language, it is proper that we should multiply the occasions of bringing us together; so far from attempting to enslave him by our language, we ought rather to inspire his confidence by learning his terms. Let us prove to the artist that our relations with him are more extended than he imagines; and let us by this intimacy establish mutual correspondence, and a concurrence of information, which cannot but redound to the advantage of the arts and of chemistry.

After having explained the principal objections which have retarded the improvement of chemistry, and the causes which in our time have accelerated its progress,

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we shall endeavour to point out the principal applications of this science ; in which attempt, we think, we shall succeed best by casting a general retrospect over those arts and sciences which receive certain principles from it.

Most of the arts are indebted to accident for their discovery. They are in general neither the fruit of research, nor the result of combination, but all of them have a more or less evident relation to chemistry. This science therefore is capable of clearing up their first principles, reforming their abuses, simplifying their operations, and accelerating their progress.

Chemistry bears the same relation to most of the arts, as the mathematics have to the several parts of science which depend on their principles. It is possible, no doubt, that works of mechanism may be executed by one who is no mathematician; and so likewise it is possible to dye a beautiful scarlet without being a chemist : but the operations of the mechanic, and of the dyer, are not the less founded upon invariable

variable principles, the knowledge of which would be of infinite utility to the artist.

We continually hear in manufactories of the caprices and uncertainty of operations ; but it appears to me that this vague expression owes its birth to the ignorance of the workmen with regard to the true principles of their art. For nature itself does not act with determination and discernment, but obeys invariable laws ; and the inanimate substance which we make use of in our manufactures, exhibits necessary effects, in which the will has no part, and consequently in which caprices cannot take place. Render yourselves better acquainted with the materials you work upon, we might say to the artists ; study more intimately the principles of your art ; and you will be able to foresee, to predict, and to calculate every effect. It is your ignorance alone which renders your operations a continual series of trials, and a discouraging alternative of success and disappointment.

The public, which continually exclaims that experience is better than science, encourages and supports this ignorance on the
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part of the artist; and it will not be remote from our object to attempt to ascertain the true value of these terms. It is very true, for example, that a man who has had a very long experience may perform operations with exactness; but he will always be confined to the mere manipulation. I would compare such a man to a blind person who is acquainted with the road, and can pass along it with ease, and perhaps even with the confidence and assurance of a man who sees perfectly well; but is at the same time incapable of avoiding accidental obstacles, incapable of shortening his way or taking the most direct course, and incapable of laying down any rules which he can communicate to others. This is the state of the artist of mere experience; however long the duration of his practice may have been, as the simple performer of operations.

It may perhaps be replied, that artists have made very important discoveries in consequence of assiduous labour. This is indeed true, but the examples are very scarce; and we have no right to conclude, because we have seen men of genius without any mathematical

thematical theory execute wonderful works of mechanism, that the mathematics are not the basis of mechanics, or that any one has a right to expect to become a great mechanic without a profound study of mathematical principles.

It appears to be generally admitted at present, that chemistry is the basis of the arts; but the artist will not derive from chemistry all the advantages he has a right to expect, until he has broken through that powerful barrier which suspicion, self-love, and prejudice have raised between the chemist and himself. Such philosophers as have attempted to pass this line, have frequently been repelled as dangerous innovators; and prejudice, which reigns despotically in manufactories, has not even permitted it to be thought that the processes were capable of improvement.

It is easy to shew the advantages which the arts might obtain from chemistry, by casting a retrospect over its applications to each of them in particular.

1. It appears, from the writings of Columella, that the ancients possessed a considerable

derable extent of knowledge respecting agriculture, which was at that time considered as the first and noblest occupation of man. But when once the objects of luxury prevailed over those of necessity, the cultivation of the ground was left to the mere succession of practice, and this first of the arts became degraded by prejudices.

Agriculture is more intimately connected with chemistry than is usually supposed. It must be admitted that every man is capable of causing ground to bear corn; but what a considerable extent of knowledge is necessary to cause it to produce the greatest possible quantity! It is not enough, for this purpose, to divide, to cultivate, and to manure any piece of ground: a mixture is likewise required of earthy principles so well assorted, that it may afford a proper nourishment; permit the roots to extend themselves to a distance, in order to draw up the nutritive juices; give the stem a fixed base; receive, retain, and afford upon occasion, the aqueous principle, without which no vegetation can be formed. It is therefore essential to ascertain the nature of the earth,
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the avidity with which it seizes water, its force of retaining it, &c.; and these requisites point to studies which will afford principles not to be obtained by mere practice but slowly and imperfectly.

Every grain requires a peculiar earth. Barley vegetates freely among the dry remains of granite; wheat grows in calcareous earth, &c. And how can it be possible to naturalize foreign products, without a sufficient stock of knowledge to supply them with an earth similar to that which is natural to them?

The disorders of grain and forage, and the destruction of the insects which devour them, are objects of natural history and chemistry: and we have seen in our own times the essential art of drying and preserving grain, and all those details which are interesting in the preparation of bread, carried by the labours of a few chemists to a degree of perfection which seemed difficult to have been attained.

The art of disposing stables in a proper manner, that of choosing water adapted for the drink of domestic animals, the æconomical

cal processes for preparing and mixing their food, the uncommon talent of supplying a proper manure suited to the nature of soils, the knowledge necessary to prevent or to repair the effects of blights—all come within the province of Chemistry; and without the assistance of this science our proceeding would be painful, slow, and uncertain.

We may at present insist upon the necessity of chemistry in the various branches of agriculture with so much the more reason, as government does not cease to encourage this first of arts by recompences, distinctions, and establishments; and the views of the state are forwarded by the proposal of means to render this art flourishing. We see, with the greatest satisfaction, that by a happy return of reflection, we begin to consider agriculture as the purest, the most fruitful, and the most natural source of our riches. Prejudices no longer tend to oppress the husbandman. Contempt and servitude are no longer the inheritance received for his incessant labours. The most useful and the most virtuous

1 *Preliminary Discourse.*

class of men is likewise that whose state is most minutely considered; and the cultivator of the ground in France is at last permitted to raise his hands in a state of freedom to Heaven, in gratitude for this happy revolution.

2. The working of mines is likewise founded upon the principles of chemistry. This science alone points out and directs the series of operations to be made upon a metal, from the moment of its extraction from the earth until it comes to be used in the arts.

Before the chemical analysis was applied to the examination of stones, these substances were all denoted by superficial characters, such as colour, hardness, volume, weight, form, and the property of giving fire with the steel. All these circumstances had given rise to methods of division in which every other property was confounded; but the successive labours of Pott, Margraaff, Bergmann, Scheele, Bayen, Dietrich, Kirwan, Lavoisier, De Morveau, Achard, Sage, Berthollett, Gerhard, Erhmann, Fourcroy, Mongez,

Mongez, Klaproth, Crell, Pelletier, De la Metherie, &c. by instructing us concerning the constituent principles of every known stone, have placed these substances in their proper situations, and have carried this part of chemistry to the same degree of precision as that which we before possessed respecting the neutral salts.

The natural history of the mineral kingdom, unassisted by chemistry, is a language composed of a few words, the knowledge of which has acquired the name of Mineralogist to many persons. The words Calcareous Stone, Granite, Spar, Schorle, Feld Spar, Schistus, Mica, &c. alone compose the dictionary of several amateurs of natural history; but the disposition of these substances in the bowels of the earth, their respective position in the composition of the globe, their formation and successive decompositions, their uses in the arts, and the knowledge of their constituent principles, form a science which can be well known and investigated by the chemist only.

It is necessary therefore that mineralogy
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should be enlightened by the study of chemistry; and we may observe that, since these two sciences have been united, the labour of working mines has been simplified; metallic ores have been wrought with more intelligence, several new metallic substances have been discovered, individuals have opened mines in the provinces; and we have become familiar with a species of industry which seemed foreign, and almost incompatible with, our soil and our habits. Steel and the other metals have received in our manufactories that degree of perfection which had till lately excited our admiration, and humiliated our self-love. The superb manufacture of Creusot has no equal in Europe. Most of our works are supported by pit-coal; and this new combustible substance is so much the more valuable, as it affords us time to repair our exhausted woods, and as it is found almost every where in those barren soils which repel the ploughshare, and prohibit every other kind of industry. The eternal gratitude of this country is therefore due to Messrs. Jars, Dietrich, Duhamel, Monet, Genfanne,

Genfanne, &c. who first brought us acquainted with these true riches. The taste for mineralogy, which has diffused itself within our remembrance, has not a little contributed to produce this revolution; and it is in a great measure owing to those collections of natural history, against which some persons have so much exclaimed, that we are indebted for this general taste. Our collections have the same relation to natural history, as books bear to literature and the sciences. The collection frequently is nothing more than an object of luxury to the proprietor; but in this very case it is a resource always open to the man who is desirous of beholding, and instructing himself. It is an exemplar of the works of nature, which may be consulted every moment; and the chemist who runs over all these productions, and subjects them to analyses to ascertain their constituent principles, forms the precious chain which unites nature and art.

3. While the chemist attends to the nature of bodies, and endeavours to ascertain their constituent principles, the natural philosopher

philosopher studies their external characters, and as it were their physiognomy. The object of the chemist ought therefore to be united to that of the philosopher, in order to acquire a complete idea of a body. What in fact shall we call Air or Fire, without the instruction of the chemist? Fluids more or less compressible, ponderous, and elastic. What are the particulars of information which natural philosophy affords us concerning the nature of solids? It teaches us to distinguish them from each other, to calculate their weight, to determine their figure, to ascertain their uses, &c.

If we cast our attention upon the numerous particulars which chemistry has lately taught us respecting air, water, and fire, we shall perceive how much the connection of these two sciences has been strengthened. Before this revolution, natural philosophy was reduced to the simple display of machines; and this obscurity, by giving it a transient glare, would have impeded its progress, if chemistry had not restored it to its true destination. The celebrated
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chancellor Bacon compared the natural magic, or experimental philosophy, of his time, to a magazine in which a few rich and valuable moveables were found among a heap of toys. The curious, says he, is exhibited instead of the useful. What more is required to draw the attention of great men, and to form that transient fashion of the day which ends in contempt?

The natural philosophy of our days no longer deserves the reproaches of this celebrated philosopher. It is a science founded on two bases equally solid. On the one part, it depends on mathematical science for its principles; and, on the other, it rests upon chemistry. The natural philosopher will attend equally to both sciences.

The study of chemistry, in certain departments, is so intimately connected with that of natural philosophy, that they are inseparable; as, for example, in researches concerning air, water, fire, &c. These sciences very advantageously assist each other in other respects; and while the chemist clears minerals from the foreign bodies

bodies which are combined with them, the philosopher supplies the mechanical apparatus necessary for exploring them. Chemistry is inseparable from natural philosophy, even in such parts as appear the most independent of it; such, for example, as optics, where the natural philosopher can make no progress but in proportion as the chemist shall bring his glass to perfection.

The connection between these two sciences is so intimate, that it is difficult to draw a line of distinction between them. If we confine natural philosophy to enquiries relative to the external properties of bodies, we shall afford no other object but the mere outside of things. If we restrain the chemist to the mere analysis, he will at most arrive at the knowledge of the constituent principles of bodies, and will be ignorant of their functions. These distinctions in a science which has but one common purpose, namely the complete knowledge of bodies, cannot longer exist; and it appears to me that we ought absolutely to reject them in all objects which can only be

be well examined by the union of natural philosophy and chemistry.

At the period of the revival of letters, it was of advantage to separate the learned, as it were, upon the road to truth; and to multiply the workshops, if I may use the expression, to hasten the clearing away. But at present, when the various points are re-united, and the connection between the whole is seen, these separations, these divisions, ought to be effaced; and we may flatter ourselves that, by uniting our efforts, we may make a rapid progress in the study of nature. The meteors, and all the phenomena of which the atmosphere is the grand theatre, can be known only by this re-union. The decomposition of water in the bowels of the earth, and its formation in the fluid which surrounds us, cannot but give rise to the most happy and the most sublime applications.

4. The connection between chemistry and pharmacy is so intimate, that these two sciences have long been considered as one and the same; and chemistry, for a long time, was cultivated only by physicians and apothecaries.

apothecaries. It must be allowed that, though the chemistry of the present day is very different from pharmacy, which is only an application of the general principles of this science, these applications are so numerous, the class of persons who cultivate pharmacy is in general so well informed, that it is not at all to be wondered at, that most apothecaries should endeavour to enlighten their profession by a serious study of chemistry, and by the happiest agreement unite the knowledge of both parts of science.

The abuses which, at the beginning of the present century, were made of the applications of chemistry to medicine; have caused the natural and intimate relations of this science with the art of healing to be mistaken. It would have been more prudent, no doubt, to have rectified its applications; but unfortunately we have too much ground to reproach physicians for going to extremes. They have, without restriction, banished that which they before received without examination; and we have seen them successively deprive
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their art of all the assistance it might obtain from the auxiliary sciences.

In order to direct with propriety the applications of chemistry to the human body, proper views must be adopted relating to the animal economy, together with accurate notions of chemistry itself. The results of the laboratory must be considered as subordinate to physiological observations. We should endeavour to enlighten the one by the other, and to admit no truth as established which is contradicted by any of these means of conviction. It is in consequence of a departure from these principles that the human body has been considered as a lifeless and passive substance; and that the strict principles observed in the operations of the laboratory have been applied to this living system.

In the mineral kingdom, every thing is subjected to the invariable laws of the affinities. No internal principle modifies the action of natural agents; and hence it arises that we are capable of foretelling, producing, or modifying the effects.

In the vegetable kingdom, the action of
external

external agents is equally evident ; but the internal organization modifies their effects, and the principal functions of vegetables arise from the combined action of external and internal causes. It was no doubt for this reason that the Creator disposed the principal organs of vegetation upon the surface of the plant, in order that the various functions might at the same time receive the impressions of external agents, and that of the internal principle of the organization.

In animals, the functions are much less dependant on external causes ; and nature has concealed the principal organs in the internal part of their bodies, as if to withdraw them from the influence of foreign powers. But the more the functions of an individual are connected with its organization, the less is the empire of chemistry over them ; and it becomes us to be cautious in the application of this science to all the phenomena which depend essentially upon the principles of life.

We must not however consider chemistry as foreign to the study and practice of medicine.

medicine. This science alone can teach us the difficulty and art of combining remedies. This alone can teach us to apply them with prudence and firmness. Without the assistance of this science, the practitioner would scarcely venture to apply those powerful remedies from which the chemical physician knows the means of deriving such great advantage. Chemistry alone, in all probability, is capable of affording means of combating epidemic disorders, which in most cases are caused by an alteration in the air, the water, or our food. It will be only in consequence of analysis that the true remedy can be found against those stony concretions which form the matter of the gout, the stone, the rheumatism, &c.; and the valuable particulars of information which we now possess respecting respiration, and the nature of the principal humours of the human body, are likewise among the benefits arising from this science.

5. Chemistry is not only of advantage to agriculture, physic, mineralogy, and medicine, but its phenomena are interesting to all

of death are developed, from which nature takes the elements of the composition of bodies, and to which their subsequent decomposition returns the same principles which were before extracted.

Chemistry, by informing us of the nature and principles of bodies, instructs us perfectly concerning our relation to the objects around us. This science teaches us, as it were, to live with them; and impresses a true life upon them, since by this means each body has its name, its character, its uses, and its influence, in the harmony and arrangement of this universe.

The chemist, in the midst of those numerous beings which the common race of men accuse nature of having vainly placed upon our globe, enjoys the prospect as it were in the centre of a society, all whose members are connected together by intimate relations, and concur to promote the general good. In his sight, every thing is animated, every being performs a part on this vast theatre; and the chemist, who participates in these interesting scenes, is repaid with usury for his first exertions
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to discover the relations existing between them.

We may even consider this commerce, or mutual relation between the chemist and nature, as very proper to soften the manners, and to impress on the character that freedom and firmness of principle so valuable in society. In the study of natural history, no cause ever presents itself to complain of inconstancy or treachery. An attachment is easily contracted for objects which afford enjoyment only; and these connections are as pure as their object, as durable as nature, and stronger in proportion to the exertions which have been required to establish them.

From all these considerations, there is no science which more eminently deserves to enter into the plan of a good education than chemistry. We may even affirm that the study of this science is almost indispensably necessary to prevent us from being strangers in the midst of the beings and phenomena which surround us. It is true indeed that the habit of beholding the objects of nature may produce a knowledge

of some of their principal properties. We may even in this way arrive at the theory of some of the phenomena. But nothing is more proper to check the pretensions of young persons who are elevated by such imperfect acquisitions, than to shew them the vast field of which they are ignorant. The profound sentiment of their ignorance will be seconded by the natural desire of acquiring new knowledge. The wonderful properties of the objects presented to them will engage their attention. The interesting nature of the phenomena will tend to excite their curiosity. Accuracy of experiment, and strictness of result, will form their reasoning powers, and render them severe in their judgment. By studying the properties of all the bodies which surround him, the young scholar learns to know their relation with himself; and by successively attending to all objects, he extends the circle of his enjoyment by new conquests. He becomes a partaker in the privileges of the Creator, by uniting and disuniting, by compounding and destroying. We might even affirm that the
Author

Author of nature, reserving to himself alone the knowledge of his general laws, has placed man between himself and matter, that it may receive these laws from his hands, and that he may apply them with proper modifications and restrictions. In this view, therefore, we may consider man as greatly superior to the other beings which compose this living system. They all follow a monotonous and invariable process; receive the laws, and submit to effects without modification. Man alone possesses the rare advantage of knowing a part of these laws, of preparing events, of predicting results, of producing effects at pleasure, of removing whatever is noxious, of appropriating whatever is beneficial, of composing substances which nature herself never forms; and, in this last point of view, himself a Creator, he appears to partake with the Supreme Being in the most eminent of his prerogatives.

The following is a list of the names of the persons who have been appointed to the various positions in the Department of the Interior, under the act of March 3, 1879, entitled "An Act to provide for the better management of the public lands, and for other purposes."

ELEMENTS OF CHEMISTRY.

PART THE FIRST.
CONCERNING THE CHEMICAL PRINCIPLES:

INTRODUCTION.

Definition of Chemistry; its Object and Means.—Description of a Laboratory, and the principal Instruments employed in chemical Operations, with a Definition of those Operations.

CHEMISTRY is a science, the object of which is to ascertain the nature and properties of bodies.

The methods used to obtain this knowledge are reducible to two; analysis and synthesis.

VOL. I.

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The principal operations of chemistry are performed in a place called a Laboratory.

A laboratory ought to be extensive and well aired, in order to prevent dangerous vapours from remaining, which are produced in some operations, or which may escape by any unforeseen accident. It ought to be dry, because otherwise iron vessels would rust, and most of the chemical products would be liable to change. But the principal excellence of a laboratory consists in its being furnished with all those instruments which may be employed in the study of the nature of bodies, and in enquiries respecting their properties.

Among these instruments there are some which are of general use, and applicable to most operations; and there are others which serve only for peculiar uses. This division immediately points out that, at the present instant, we can only treat of the former, and that we must describe the others on such occasions as will render it necessary to treat of their uses.

The chemical instruments most frequently employed are those which present themselves first to view upon entering a laboratory; namely, the furnaces.

These furnaces consist of earthen vessels appropriated to the various operations performed upon bodies by means of fire.

A proper

A proper mixture of sand and clay is commonly the material of which these vessels are formed. It is difficult, and even impossible, to prescribe and determine, according to any invariable method, the proportions of these constituent parts; because they must be varied according to the nature of the earths made use of. Habit and experience alone can furnish us with principles on this subject.

The several methods of applying fire to substances under examination have occasioned the construction of furnaces in different forms, which we shall at present reduce to the three following.

I. The evaporatory furnace.—This furnace has received its name from its use. It is used to reduce liquid substances into vapour by means of heat, in order to separate the more fixed principles from those which are more ponderous; and were mixed, suspended, compounded, or dissolved in the fluid.

The fire-place is covered by the evaporatory vessel. Two or three grooves, channels, or depressions are made in the sides of the furnace, near its upper edge, to facilitate the drawing of the fire.

The vessel which contains the substance to be evaporated, is called the evaporatory vessel.

These vessels are formed of earth, glass, or metal. Vessels of unglazed earth are too porous, inasmuch that liquids filtrate through their texture. Those of porcelain biscuit are likewise penetrable by liquids strongly heated, and suffer gaseous or æriform substances to escape. The beautiful experiment of Mr. D'Arcet upon the combustion and destruction of the diamond, in balls of porcelain, are well known, and tend to illustrate this subject. I have confirmed these results by experiments in the large way, upon the distillation of aquafortis, which loses as well in quality as quantity when the process is carried on in vessels of porcelain clay.

Glaazed earthen vessels cannot be used when the glass consists of the calces of lead or copper ; because those metallic matters are attacked by acids, fats, oils, &c. Neither can earthen vessels be used which are covered with enamel, because this kind of opaque glass is almost always full of small cracks through which the liquid would introduce itself into the body of the vessel.

Earthen vessels cannot therefore be used, excepting in operations of little delicacy, in which precision and accuracy are not indispensably required.

Evaporatory

Evaporatory vessels of glass are in general to be preferred. Those which resist the fire better than any others, are prepared in the laboratory, by cutting a sphere of glass or a receiver into two equal parts with a red-hot iron. The capsules which are made in the glass-house are thickest at the bottom, and consequently are more liable to break at that part when exposed to the fire.

Evaporatory vessels of metal are used in manufactories. Copper is most commonly employed, because it not only possesses the property of resisting fire, but has a considerable degree of solidity, together with the facility of being wrought. Alembics are made of this metal, for the distillation of vinous spirits, and aromatic substances; as are also caldrons or pots for crystallization of certain salts, and for several dyeing processes, &c. Lead is likewise of considerable use, and is made choice of whenever operations are to be performed upon substances which contain the sulphuric acid, such as the sulphates of alumine and of iron; and for the concentration and rectification of the oils of vitriol. Tin vessels are also employed in some operations: the scarlet bath affords a more beautiful colour in boilers of this metal than in those of any other. Capitals of tin

tin have already begun to be substituted in the room of those of copper, in the construction of alembics; and by this means the several products of distillation are exempted from every suspicion of that dangerous metal. Boilers of iron are likewise used for certain coarse operations; as for example, in the concentration of the lixiviums of common salt, of nitre, &c.

Evaporatory vessels of gold, of silver, or of platina, are to be preferred in some delicate operations; but the price and scarcity of these vessels do not permit them to be used, especially in the large way.

Moreover it is from the nature of the substance to be evaporated, that we must determine the choice of the vessel most suitable to any operation. There is no particular kind of vessels which can be adapted exclusively on all occasions. It may only be observed, that glass presents the greatest number of advantages, because it is composed of a substance the least attacked, the least soluble, and the least destructible by chemical agents.

Evaporatory vessels are known by the name of capsules, cucurbits, &c. according to their several forms.

These vessels ought in general to be very wide and shallow, in order that the distillation

lation and evaporation may be speedy and æconomical. It is necessary, 1. That the evaporatory vessel be not narrow at its upper part. 2. That the heat be applied to the liquid in all parts, and equally. 3. That the column or mass of the liquid should have little depth, and a large surface of evaporation. It is upon these principles that I have constructed, in Languedoc, boilers proper for distilling brandy, which save eleven-twelfths of the time, and four-fifths of the combustibles.

Evaporation may be performed in three-manners. 1. By a naked fire. 2. By the sand bath. 3. By the water bath.

Evaporation is made by a naked fire, when there is no substance interposed between the fire and the vessel which contains the liquid intended to be evaporated; as, for example, when water is boiled in a pot.

Evaporation is performed by the sand bath, when a vessel filled with sand is interposed between the fire and the evaporatory vessel. The heat is in this case communicated more slowly and gradually; and the vessels, which would otherwise have been broken by the immediate application of the heat, are enabled to resist its force. The heat is at the same time more equally kept up; the refrigeration is more gradual;

dual ; and the operations are performed with a greater degree of order, precision, and facility. If, instead of employing a vessel filled with sand, we use a vessel of water, and the evaporatory vessel be plunged in the liquid, the evaporation is said to be made on the water bath : in this case, the substance to be evaporated is only heated by communication from the water. This form or method of evaporation is employed when certain principles of great volatility, such as alcohol, or the aromatic principles of plants, are to be extracted or distilled. It possesses the advantage of affording products which are not changed by the fire, because the heat is transmitted to them by the intervention of a liquid : it is this circumstance which renders the process valuable for the extraction of volatile oils, perfumes, ethereal liquids, &c. It possesses the advantage of affording a heat nearly equal, because the degree of ebullition is a term nearly constant ; and this standard heat may be graduated or varied at pleasure, by adding salts to the liquid of the water bath, because this single circumstance renders the ebullition more or less quick and easy. The same effect may likewise be produced by restraining the evaporation ; for in this case the liquid may assume a degree of heat much more considerable,

as

as is seen in the digester of Papin, steam engines, colipiles, and the boilers for striking the red tinge in cotton.

Sublimation differs from evaporation, because the substance to be raised is solid. The vessels used in this operation are known by the name of sublimatory vessels. These are commonly globes terminating in a long neck: they are then called mattraffes.

In order to sublime any substance, a part of the ball of the mattraff is surrounded with sand. The matter which is volatilized by the heat, rises, and is condensed against the coldest part of the vessel; where it forms a stratum or cake, that may be taken out by breaking the vessel itself. In this manner it is that sal ammoniac, corrosive sublimate, and other similar products, are formed for the purposes of commerce.

Sublimation is usually performed either for the purpose of purifying certain substances, and disengaging them from extraneous matters; or else to reduce into vapour, and combine under that form, principles which would have united with great difficulty if they had not been brought to that state of extreme division.

II. The reverberatory furnace.—The name of the reverberatory furnace has been given to
that

that construction which is appropriated to distillation.

This furnace is composed of four parts. 1. The ash-hole, intended for the free passage of the air, and to receive the ashes or residue of the combustion. 2. The fire-place, separated from the ash-hole by the grate, and in which the combustible matter is contained. 3. A portion of a cylinder, which is called the laboratory, because it is this part which receives the retorts employed in the operations or distillations. 4. These three pieces are covered with a dome, or portion of a sphere, pierced near its upper part by an aperture, which affords a free passage to the current of air, and forms a chimney. The most usual form of the reverberatory furnace is that of a cylinder terminated by a hemisphere, out of which arises a chimney of a greater or less length, to produce a suitable degree of aspiration.

In order that a reverberatory furnace may be well proportioned, it is necessary, 1. That the ash-hole should be large, to admit the air fresh and unaltered. 2. That the fire-place and laboratory together should have the form of a true ellipsis, whose two foci should be occupied by the fire and the retort. In this case all
the

the heat, whether direct or reflected, will strike the retort.

The reverberatory furnace is used for distillation. Distillation is that process by which the force of fire is applied to disunite and separate the several principles of bodies, according to the laws of their volatility, and their several affinities.

Distilling vessels are known by the name of retorts.

Retorts are formed of glass, of stone-ware, of porcelain, or of metal; these substances being respectively used, according to the nature of the bodies intended to be exposed to distillation.

Whatever be the nature of the material, the forms of retorts are the same. This figure resembles an egg, terminating in a beak or tube, which diminishes insensibly in diameter, and is slightly inclined or bended.

The oval portion of the retort, which is called its belly, is placed in the laboratory of the furnace, and is supported upon two bars of iron, which separate the laboratory from the fire-place; while the beak or neck of the retort issues out of the furnace through a circular aperture formed in the edges of the dome and of the laboratory.

A vessel intended to receive the product of
the

the distillation is fitted to the neck of the retort. This vessel is called the recipient, or receiver.

The receiver is commonly a sphere with two apertures; the one of considerable magnitude, to receive the neck of the retort; the other smaller, to afford vent for the vapours. This part is called the tubulure of the receiver; whence the terms tubulated receiver, or receiver not tubulated, &c.

Though the reverberatory furnace be particularly adapted to distillation, this operation may be performed on the sand-bath; and here, as in other cases, it depends singly on the intelligence of the artist to vary his apparatus according to the necessity of circumstances, and the nature of the substances upon which he operates.

The construction of these furnaces may likewise be varied; and the chemist will find it necessary to learn the art of availing himself of every apparatus he possesses, to carry his operations into execution: for if he should persuade himself that it is impossible to proceed in chemical research, excepting in a laboratory provided with all suitable vessels, he may let the moment pass in which a discovery might be made, but which may not again return.

And

And it may be truly said, that he who treads fervilely in the paths of others who have gone before him, will never attain to the discovery of new truths.

III. The forge furnace.—The forge furnace is that in which the current of air is determined by bellows. The ash-hole, the fire-place, and the laboratory are here all united together; and this assemblage forms only a portion of a cylinder, pierced near the lower angle by a small hole, into which the tube of the bellows enters. This part is sometimes covered with a hemisphere or dome, to concentrate the heat with greater efficacy, and to reflect it upon the bodies exposed to it. The forge furnace is employed in the fusion and calcination of metals, and generally for all the operations which are performed in crucibles.

By crucibles we understand vessels of earth or metal, which are almost always of the form of an inverted cone. A crucible ought to support the strongest heat without melting; it ought to resist the attacks of all such agents as are exposed to heat in vessels of this kind. Those crucibles which possess the greatest degree of perfection, are made in Hesse or in Holland. I have made very good ones by a
mixture

mixture of raw and unbaked clay from Salavas in the Vivarais.

Our laboratories have been provided with crucibles of platina, which unite the most excellent properties. They are nearly infusible, and at the same time indestructible by the fire.

The several earthen vessels concerning which we have here treated, may be fabricated by hand, or wrought in the lathe. The first proceeding renders them more solid, the clay is better united, and it is the only method used in glass manufactories; but the second method is more expeditious.

The agent of such decompositions as are effected by means of furnaces, is fire. It is afforded by the combustion of wood, pit-coal, or charcoal.

Wood is only employed in certain large works; and we prefer charcoal in our laboratories, because it does not smoke, has no bad smell, and burns better in small masses than other combustibles. We choose that which is the most sonorous, the driest, and the least porous.

But, in the several operations we are about to describe, it is necessary to defend the retorts from the immediate action of the fire; and also to coerce and restrain the expansible vapours,

vapours, which are very elastic, and frequently corrosive. It is to answer these purposes that various lutes are employed.

1. A glass retort exposed to the action of the fire would infallibly break, if the operator were not to have recourse to the prudent precaution of coating it with earth.

- I have found it advantageous for the coating of retorts, to use a mixture of fat earth and fresh horse dung : for this purpose, the fat earth is suffered to rot for some hours in water ; and when it is moistened, and properly softened, it must be kneaded with the horse dung, and formed into a soft paste, which is to be applied and spread with the hand upon every part of the retort intended to be exposed to the action of the fire. The horse dung combines several advantages. 1. It contains a serous fluid, which hardens by heat, and strongly connects all the parts together : when this juice has been altered by fermentation or age, the dung does not possess the same virtue. 2. The filaments or stalks of hay, which are so easily distinguished in horse dung, unite all the parts of the lute together.

Retorts luted in this manner resist the impression of the fire very well ; and the adhesion of the lute to the retort is such, that even should the

the retort fly during the operation, the distillation may be still carried on, as I have daily experience in works in the large way.

2. When it is required to coerce or oppose the escape of the vapours which are disengaged during any operation, it is no doubt sufficient if the joinings of the vessels be covered with paper glued on, or with slips of bladder moistened with the lute of lime and white of egg, provided the vapours be neither dangerous nor corrosive; but, when the vapours are corrosive, it is necessary to use the fat lute to retain them.

Fat lute is made with boiled linseed oil mixed and well incorporated with sifted clay. Nut oil, kneaded with the same clay, forms a lute possessing the same properties. It is easily extended in the hand, and is used for defending the joinings of vessels, upon which it is afterwards secured by strips of linen, dipped in the lute of lime and white of egg. Before the application of heat in any distillation, it is necessary first to suffer the lutes to dry. Without this precaution, the vapours would rise and escape; or otherwise they would combine with the water which moistens the lutes, and would corrode and destroy the bladder, the skin, the paper, and in a word every substance used to secure them in their places. The lute of lime and
white

white of egg dries very speedily, and must be used the moment it is made. This lute, likewise, opposes the greatest resistance to the escape of the vapours, and adheres the most intimately to the glass. It is made by mixing a small quantity of finely-powdered quick-lime with white of egg, and afterwards beating up the mixture to facilitate the combination. It must then be instantly applied on pieces of old linen, to be wrapped round the places of joining.

In the large works, where it is not possible to attend to all these minute details, the joinings of the retort and receiver are luted together with the same lute which is used to coat the retorts. A covering of the thickness of a few lines is sufficient to prevent the vapours of the marine or nitrous acid from escaping.

As in certain operations a disengagement takes place of so prodigious a quantity of vapours, that it is dangerous to confine them; and as, on the other hand, the suffering them to escape would occasion a considerable loss in the product; an apparatus has been contrived of great ingenuity and simplicity to moderate the issue, and to retain without risk such vapours as would otherwise escape. This apparatus is known by the name of its author, Mr. Woulfe, a famous English chemist. His most

excellent process consists in adapting the extremity of a recurved tube to the tubulure of the receiver; the other end of which is plunged into water, in a bottle half filled, and properly placed for that purpose. From the empty part of this bottle issues a second tube, which is in like manner plunged in the water of a second bottle. A number of other bottles may be added, observing the same precautions; with the attention, nevertheless, to leave the last open, to give a free escape to the vapours which are not coercible: and, when the apparatus is thus disposed, all the joinings are to be luted. It will easily be imagined that the vapours which escape from the retort are obliged to pass through the tube adapted to the tubulure of the receiver, and consequently must pass through the water of the first bottle: they therefore suffer a first resistance, which partly condenses them. But as almost all vapours are more or less miscible and soluble in water, a calculation is previously made of the quantity of water necessary to absorb the vapours which are disengaged from the mixture in the retort; and care is taken to distribute this proper quantity of water in the bottles of the apparatus.

By this means we obtain the purest and most concentrated products; because the water, which

which is always the receiver, and is the vehicle of these substances, becomes saturated with them. There is, perhaps, no other method of obtaining products always of an equal energy, and comparable in their effects; a circumstance of the greatest importance in the operations of the arts, as well as in philosophical experiments.

I have applied this apparatus to works in the large way; and I use it to extract the common muriatic acid, the oxygenated muriatic acid, ammoniac or volatile alkali, &c.

As it would very often happen, in this apparatus, that the pressure of the external air would cause the water of the outer vessels to pass into the receiver, in consequence of the simple refrigeration of the retort; this inconvenience has been obviated, by inserting a straight tube into the necks of the first and the second bottles, to such a depth, that its lower end is plunged into the water, while its other end rises several inches above the neck of the bottle. It may easily be conceived, as a consequence of this disposition, that when the dilated vapours of the receiver and retort are condensed by cooling, the external air will rush through these tubes to establish the equilibrium; and the water cannot pass from the one to the other.

Before the invention of this apparatus, it was usual

usual to drill a hole in the receiver, which was kept closed, and only opened from time to time for the escape of the vapours. This method was inconvenient in many respects. In the first place; and principally, because, in spite of all precautions, it was attended with the risk of an explosion every moment, by the irregular disengagement of the vapours, and the impossibility of calculating the quantity produced in a given time. A second inconvenience was, that the vapours which thus escaped occasioned a considerable loss in the product; and even weakened the remainder; because this volatile principle consisted of the strongest part. A third inconvenience was, that the vapours which did escape incommoded the artist to such a degree, that it was impossible to perform most of the operations of chemistry in the course of a lecture, where a considerable number of auditors were present.

Thus it is that the apparatus of Woulfe unites a number of advantages: on the one hand, economy in the processes, and superiority in the product; on the other hand, safety for the chemist and his assistants: and, in every point of view, the author is entitled to the best acknowledgments of chemists, who were too often so much affected with these unwholesome exhalations,

exhalations, that their health was either totally destroyed, or they fell absolute victims to their zeal for the promotion of science.

It is necessary that a laboratory should be provided with balances of the utmost accuracy; for the chemist, who very frequently operates only upon small quantities, ought to be able, by the strictness of his operations, and the accuracy of his apparatus, to produce results comparable with those of works in the large way. It frequently happens that the simple essay of a specimen of an ore determines the opening of a mine; and it scarcely need be pointed out, of how great consequence it is to remove every cause of error from the operations of chemistry; since the slightest error in the works of the laboratory may be attended with the most unhappy consequences, when the application of the principles is made to works in the large way.

We shall treat of other vessels and chemical apparatus, in proportion as we shall have occasion to make use of them; for it appears to us that, by thus connecting the description with their use, we shall succeed better in rendering them intelligible to the reader, at the same time that his memory will be less fatigued.

SECTION I.

Concerning the General Law which tends to bring the Particles of Bodies together, and to maintain them in a State of Mixture or Combination.

THE Supreme Being has given a force of mutual attraction to the particles of matter; a principle which is alone sufficient to produce that arrangement which the bodies of this universe present to our observation. As a very natural consequence of this primordial law, it follows that the elements of bodies must have been urged towards each other; that masses must have been formed by their re-union; and that solid and compact bodies must have insensibly been constituted; towards which, as towards a centre, the less heavy and less compact bodies must gravitate.

This law of attraction, which the chemists call Affinity, tends continually to bring principles together which are disunited, and retains with more or less energy those which are already in combination; so that it is impossible to produce any change in nature, without interrupting or modifying this attractive power.

It

It is natural, therefore, and even indispensable that we should speak of the law of the affinities before we proceed to treat of the methods of analysis.

Affinity is exercised either between principles of the same nature, or between principles of a different nature.

We may, therefore, distinguish two kinds of affinity, with respect to the nature of bodies.

1. The affinity of aggregation, or that which exists between two principles of the same nature.
2. The affinity of composition, or that which retains two or more principles of different natures in a state of combination.

Of the Affinity of Aggregation.

Two drops of water which unite together into one, form an aggregate, of which each drop is known by the name of an integrant part.

An aggregate differs from a heap; because the integrant parts of this last have no perceptible adhesion to each other; as, for example, a heap of barley, of sand, &c.

An aggregate, and a heap, differ from a mixture; because the constituent parts of this last are of a different nature; as, for example, in gun-powder.

The affinity of aggregation is stronger, the nearer

nearest the integrant parts approach to each other; so that every thing which tends to separate or remove these integrant parts from each other, diminishes their affinity, and weakens their force of cohesion.

Heat produces this effect upon most known bodies: hence it is that melted metals have no consistence. The caloric, or matter of heat, by combining with bodies, almost always produces an effect opposite to the force of attraction; and we might consider ourselves as authorised to affirm that it is a principle of repulsion, if sound chemistry had not proved that it produces this effect only by its endeavour to combine with bodies, and thereby necessarily diminishing their force of aggregation, as all other chemical agents do. Besides which, the extreme levity of caloric produces the effect that, when it is combined with any given body, it continually tends to elevate it, and to overcome that force which retains it, and precipitates it towards the earth.

The mechanical operations of pounding, of hammering, or of cutting, likewise diminish the affinity of aggregation. They remove the integrant parts to a distance from each other; and this new disposition, by presenting a less degree of adhesion, and a larger surface, facilitates the
immediate

immediate action, and augments the energy, of chemical agents. It is for this purpose that bodies are divided when they are to be analysed, and that the effect of re-agents is facilitated by the action of heat.

The mechanical division of bodies is more difficult, the stronger their aggregation.

Aggregates exist under different states; they are solid, liquid, æriform, &c.—See Fourcroy's Chemistry.

Of the Affinity of Composition.

Bodies of different kinds exert a tendency or attraction upon each other, which is more or less strong; and it is by virtue of this force that all the changes of composition or decomposition observed among them, are effected.

The affinity of composition exhibits invariable laws in all the phenomena it causes. We may state these laws as general principles; to which may be referred all the effects presented to our observation by the action of bodies upon each other.

1. The affinity of composition acts only between the constituent parts of bodies.

The general law of attraction is exerted upon the masses; and in this respect it differs from the law of the affinities, which does not perceptibly

tibly act but on the elementary particles of bodies. Two bodies placed near each other do not unite; but, if they be divided and mixed, a combination may arise. We have examples of this when the muriate of soda, or common salt, is triturated with litharge; the muriate of ammoniac, or common sal ammoniac, with lime, &c. And it may be asserted, that the energy of the affinity of composition is almost always proportioned to the degree of the division of bodies.

II. The affinity of composition is in the inverse ratio of the affinity of aggregation.

It is so much the more difficult to decompose a body, as its constituent principles are united or retained by a greater force. Gases, and especially vapours, continually tend to combination, because their aggregation is weak: and nature, which is constantly renewing the productions of this universe, never combines solid with solid; but, reducing every thing into the form of gas, by this means breaks the impediments of aggregation; and these gases uniting together, form solids in their turn.

Hence, no doubt, it arises, that the affinity of composition is so much the more strong as bodies approach nearer to the elementary state; and we shall observe, on this subject, that this law of nature is founded in wisdom: for if the
force

force or affinity of composition did not increase in proportion as bodies were brought to this degree of simplicity; if bodies did not assume a decided tendency to unite and combine, in proportion as they approach to their primitive or elementary state; the mass of elements would continually increase by these successive and uninterrupted decompositions; and we should insensibly return again to that chaos or confusion of principles, which is supposed to have been the original state of this globe.

The necessity of this state of division, which is so proper to increase the force of affinity, has caused it to be admitted as an incontestable principle; that the affinity of composition does not take place, unless one of the bodies be in the fluid state: *corpora non agunt nisi sint fluida*. But it seems to me that extreme division might be substituted instead of dissolution; for both these operations tend only to attenuate bodies, without altering their nature. It is by virtue of this division, which is equivalent to dissolution, that the decomposition of muriate of soda is effected by trituration with minium; as well as the union of cold and dry alkali with antimony, and the disengagement of volatile alkali by the simple mixture of sal ammoniac with lime.

III. When two or more bodies unite by the

the affinity of composition, their temperature changes.

This phenomenon cannot be explained but by considering the fluid of heat as a constituent principle of bodies, unequally distributed amongst them; so that, when any change is produced in bodies, this fluid is displaced in its turn, which necessarily produces a change of temperature. We shall return to those principles when we speak of heat.

IV. The compound which results from the combination of two bodies, possesses properties totally different from those of its constituent principles.

Some chemists have affirmed, that the properties of compounds were intermediate between those of their constituent parts. But this term "intermediate" has no meaning in the present case; for what intermediate qualities can exist between sour and sweet, or between water and fire?

If we attend ever so little to the phenomena which are exhibited to us by bodies in their composition, we shall perceive that their form, their taste, and their consistence, are changed in combination; and we cannot establish any rule to indicate, *a priori*, all the changes which may arise, and the nature and properties of the body which shall be formed.

V. Every

V.. Every individual substance has its peculiar affinities with the various substances presented to it.

If all bodies had the same degree of affinity with each other, no change could take place amongst them: we should not be able to displace any principle by presenting one body to another. Nature has therefore wisely varied the affinities, and appointed to each body its relation with all those that can be presented to it.

It is in consequence of this difference in the affinities that all chemical decompositions are effected: all the operations of nature and art are founded upon it. It is therefore of importance to be well acquainted with all the phenomena and circumstances which this law of decomposition can present to us.

The affinity of composition has received different names, according to its effects. It is divided into simple affinity, double affinity, the affinity of an intermedium, reciprocal affinity, &c.

1. Two principles united together, and separated by means of a third, afford an example of simple affinity: it consists in the displacing of one principle by the addition of a third. Bergman has given it the name of Elective Attraction.

The body which is disengaged, or displaced,

is

is known by the name of the Precipitate. An alkali precipitates metals from their solutions; the sulphuric acid precipitates the muriatic, the nitric, &c.

The precipitate is not always formed by the disengaged substance. Sometimes the new compound itself is precipitated; as, for example, when I pour the sulphuric or vitriolic acid on a solution of muriate of lime. Sometimes the disengaged body and the new compound are precipitated together; as, for example, when the sulphate of magnesia or Epsom salt is dissolved in water, and precipitated by means of lime-water.

2. It often happens that the compound of two principles cannot be destroyed either by a third or a fourth body separately applied; but if these two bodies be united, and placed in contact with the same compound, a decomposition or change of principles will then take place. This phenomenon constitutes the double affinity. An example will render this proposition more clear and precise. The sulphate of pot-ash or vitriolated tartar is not completely decomposed by the nitric acid or by lime, when either of these principles is separately presented; but, if the nitric acid be combined with lime, this nitrate of lime will decompose the sulphate of pot-ash.

pot-ash. In this last case the affinity of the sulphuric acid with the alkali is weakened by its affinity to the lime. This acid, therefore, is subject to two attractions; the one which retains it to the alkali, and the other which attracts it towards the lime: Mr. Kirwan has named the first the *Quiescent Affinity*, the other the *Divellent Affinity*. The same may be said respecting the affinities of the alkali; it is retained to the sulphuric acid by a superior force, but nevertheless attracted by the nitric acid. Let us suppose, now, that the sulphuric acid adheres to the alkali with a force as 8, and to the lime by a force expressed by the number 6; that the nitric acid adheres to the lime by a force as 4, and tends to unite with the alkali by a force as 7. It may then be perceived that the nitric acid and the lime, separately applied to the sulphate of pot-ash, would not produce any change: but if they be presented in a state of combination, then the sulphuric acid is attracted on the one hand by 6, and retained by 8; it has therefore an effective attraction to the alkali as 2. On the other hand, the nitric acid is attracted by a force as 7, and retained by a force as 4; it therefore retains a tendency to unite with the alkali, which is denoted by the number 3; and consequently it ought to displace the sulphuric

phuric acid, which is retained only by a force

as 26

3^d There are cases in which two bodies, having no perceptible affinity to each other, obtain a disposition to unite by the intervention of a third; and this is called the affinity of an intermedium. An alkali is the intermedium of union between oil and water; hence the theory of lixiviums, of washing, &c. &c.

If the affinities of bodies were well known, we might foretel the results of all operations: but it is obvious how difficult it must be to acquire this extensive knowledge of nature; more especially since modern discoveries have exhibited to us an infinity of modifications in our processes, and have shewn that results may vary with such facility, that even the absence or presence of light will render them very different.

As long as chemistry was confined to the knowledge of a few substances, and was busied only in attending to a certain number of facts, it was possible to draw up tables of affinity, and to exhibit the result of our knowledge in one and the same table. But all the principles upon which these tables have been constructed, have received modifications; the number of principles has increased; and we find ourselves under the necessity of labouring upon new ground.

ground. A sketch of this great work may be seen in the Essay on Affinities of the celebrated Bergman, and in the article Affinity in the *Encyclopédie Méthodique*.

VI. The particles which are brought together and united by affinity, whether they be of the same nature or of different natures, continually tend to form bodies of a polyhedral, constant, and determinate form.

This beautiful law of nature, by which she impresses on all her productions a constant and regular form, appears to have been unknown to the ancients: and when chemists began to discover that almost all bodies of the mineral kingdom affected regular forms, they at first distinguished them according to the inaccurate resemblance supposed to exist between them and other known bodies. Hence the denomination of crystals in pyramids, needles, points of diamonds, crosses, sword blades, &c.

We are more particularly indebted to the celebrated Linnæus for the first precise ideas of these geometrical figures. He took notice of the constancy and uniformity of this character; and this celebrated naturalist thought himself authorised to make it the basis of his method of classification of the mineral kingdom.

Mr. Romé de Lisse has proceeded still far-

VOL. I.

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ther: he has subjected all the forms to a strict examination; he has, as it were, decomposed them; and is of opinion that he can distinguish in the crystals of all analogous or identical substances, the simple modifications and shades of a primitive form. By this means he has reduced all the confused and irregular forms to certain primitive figures; and has attributed to nature a plan or primitive design, which she varies and modifies in a thousand manners, according to circumstances that influence her proceedings. This truly great and philosophical work has rendered this part of mineralogy in the highest degree interesting; and if we should admit that Mr. De Lisle has perhaps carried these resemblances too far, we cannot but allow that he deserves a distinguished place amongst those authors who have contributed to the progress of science. The Crystallographie of this celebrated naturalist may be perused with advantage.

The abbé Haüy has since applied calculation to observation. He has undertaken to prove that each crystal has a nucleus or primitive form; and has shewn the laws of diminution to which the component laminæ of the crystals are subject, in their transition from the primitive to the secondary forms. The development of these

these fine principles, and their application to crystals the best known, may be seen in his theory of the structure of crystals, and in several of his memoirs printed in the volumes of the Academy of Sciences.

The united labours of these celebrated naturalists have carried crystallography to a degree of perfection of which it did not appear susceptible. But we shall, at this moment, attend only to the principles according to which crystallization is effected.

To dispose a substance to crystallization, it is necessary in the first place to reduce it to the most complete state of division.

This division may be effected by solution, or by an operation purely mechanical.

Solution may be effected either by the means of water or of fire. The solution of salts is in general performed in the first liquid, that of metals is effected by means of the second; and their solution is not complete until a degree of heat is applied of sufficient intensity to convert them into the state of gas.

When the water which holds any salt in solution is evaporated, the principles of the dissolved body are insensibly brought nearer to each other, and it is obtained in a regular form. The same circumstance nearly takes place in

the solution by fire. When a metal is impregnated with this fluid, it does not crystallize but in proportion as this excess of igneous fluid is withdrawn.

In order that the form of a crystal may be regular, three circumstances are required; time, a sufficient space, and repose. Consult: Linnæus, Daubenton, &c.

A. Time causes the superabundant fluid to be slowly dissipated, and brings the integral parts nearer to each other by insensible gradation, and without any sudden shock. These integrant parts therefore unite according to their constant laws, and form a regular crystal. For this reason it is, that slow evaporation is recommended by all good chemists. Vide: Stahl's Treatise on Salts, chap. 29.

In proportion as the evaporation of the solvent is effected, the principles of the dissolved body approach each other, and their affinity is continually augmented while that of the solvent remains unaltered. Hence it arises, no doubt, that the last portions of the solvent are most difficultly volatilized, and that salts retain a greater or less quantity, which forms their water of crystallization. The proportion of water of crystallization not only varies greatly in the different salts, but it adheres with greater
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or less strength. There are some which suffer this water to fly off when they are exposed to the air; such as soda or the mineral alkali, the sulphate of soda or Glauber's salt, &c. In this situation these salts lose their transparency, and fall into powder: they are then said to have effloresced. There are other salts which obstinately retain their water of crystallization; such as the muriate of pot-ash, the nitrate of pot-ash or common nitre, &c.

The phenomena presented to us by the different salts, when forcibly deprived of their water of crystallization, exhibit other varieties. Some crackle with the heat, and are thrown about in small pieces when the water is dissipated: this appearance is called decrepitation. Others emit the same water in the form of steam, and are liquefied with a diminution of their bulk. Others again swell up, and become converted into a blistered or porous substance.

We are indebted to Mr. Kirwan for an accurate table of the water of crystallization contained in each salt. This table may be seen by consulting his *Mineralogy*.

The simple cooling of the fluid which holds the salt in solution may precipitate a considerable quantity. The caloric and the water dissolve a greater quantity of salt when their action

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is united; and it may easily be imagined that the subtraction of one of the solvents must occasion the precipitation of that portion which it held in solution. Thus it is that warm water saturated with salt must suffer a part to precipitate by cooling; and for this reason crystallization always begins at the surface of the liquid, and on the sides of the containing vessel; namely, because these parts are the first which suffer refrigeration.

It is the alternation of heat and cold which causes the atmosphere to dissolve sometimes a greater, and sometimes a less quantity of water; and constitutes mists, the evening dew, &c.

The mutual approach of the constituent parts of a body held in solution may be likewise accelerated by presenting to the water which suspends them, another body which has a strong affinity to it. It is upon this principle that alcohol precipitates several salts.

B. Space or sufficient room is likewise a condition necessary for obtaining regular crystallization. If nature be restrained in her operations, the product of her labour will exhibit symptoms of this state of constraint. It may be asserted that nature forms her productions according to all the circumstances which may influence her operations.

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C. A state of repose in the fluid is likewise necessary to obtain very regular forms. Uninterrupted agitation opposes all symmetrical arrangement; and in this case the crystallization obtained will be confused and indeterminate.

I am persuaded that, in order to obtain bodies under the form of crystals, a previous solution is not necessary, but that a simple mechanical division would be sufficient. To obtain a conviction of this truth, it is only necessary to observe that solution does not change the nature of bodies, but simply procures an extreme state of division; so that the disunited principles approaching each other very gradually and without starts, can adapt themselves to each other, by following the invariable laws of their gravity and affinity. Now a division purely mechanical produces the same effect, and places the principles in the same disposition. We ought not therefore to be surprised if most salts, such as gypsum, when dispersed in the earth, should assume regular forms without any previous solution; neither ought we to think it strange if the imperceptible fragments of quartz, of spar, &c. when carried along and prodigiously divided by the action of waters, should be deposited in the form of regular crystals.

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40 *Cryſtallization. Saline Vegetation.*

A very ſingular property may be obſerved in ſalts; which may be referred to cryſtallization, but is likewiſe in ſome meaſure remote from it, becauſe it does not depend upon the ſame cauſes. This is the property of riſing along the ſides of the veſſels which contain the ſolution. It is known by the name of Saline Vegetation.

I have firſt demonſtrated that this phenomenon depends on the concurrence of air and light; and that the effect may be determined at pleaſure towards any part of the veſſel, by managing and directing the action of theſe two agents.

I have ſhewn the principal forms which this ſingular vegetation affects. The detail of my experiments may be ſeen in the third volume of the Memoirs of the Academy of Toulouſe.

Mr. Dorthes has confirmed my reſults; and has moreover obſerved that camphor, ſpirits of wine, water, &c. which riſe by inſenſible evaporation in half-filled veſſels, conſtantly attach themſelves to the moſt enlightened parts of the veſſels.

Meſſrs. Petit and Rouelle have treated on the vegetation of ſalts; but a ſeries of experiments on the ſubject was wanting. This is what we have endeavoured to ſupply.

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SECTION II.

Concerning the various Means employed by Chemists to overcome the Adhesion which exists between the Particles of Bodies. •

THE law of affinities, towards which our attention has been directed, tends continually to bring the particles of bodies into contact, and to maintain them in their state of union. The efforts of the chemist are almost all directed to overcome this attractive power, and the means he employs are reducible to—
1. The division of bodies by mechanical operations. 2. The division or separation of the particles from each other by the assistance of solvents. 3. The means of presenting to the several principles of the same bodies, substances which have a stronger affinity to them than those principles have to each other.

I. The different operations performed upon bodies by the chemist, to determine their nature, alter their form, their texture, and even in
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some instances change their constitution. All these changes are either mechanical or chemical.

The mechanical operations we shall at present describe do not change the nature of substances, but in general change only their form and bulk. These operations are performed by the hammer, the knife, the pestle, &c. Whence it follows, that the chemical laboratory ought to be provided with all these instruments.

These divisions or triturations are performed in mortars of stone, of glass, or of metal. It is the nature of the substance under examination which determines the use of one or the other of these vessels.

The object of these preliminary operations is, to prepare and dispose bodies for new operations which may disunite their principles and change their nature; these last-mentioned operations, which may be distinguished by the appellation Chemical, are what most essentially constitute the analysis.

II. The solution to which we are at present to attend, consists in the division and disappearance of a solid in a liquid, but without any alteration in the nature of the body so dissolved.

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The liquid in which the solid disappears, is called the solvent or menstruum.

The agent of solution appears to follow certain constant laws, which we shall here point out.

A. The agent of solution does not appear to differ from that of affinity; and in all cases the solution is more or less abundant, the greater the affinity of the integrant parts of the solvent is to those of the body to be dissolved.

From this principle it follows, that, to facilitate solution, it is necessary that bodies should be triturated and divided. By this means a greater number of surfaces are presented, and the affinity of the integrant parts is diminished.

It sometimes happens that the affinity between the solvent and the body presented to it has so little energy, that it does not become perceptible till after a considerable interval of time. These slow operations, of which we have some examples in our laboratories, are common in the works of nature; and it is probably to similar causes that we ought to refer most of those results whose causes or agents escape our perception or observation.

B. Solution is more speedy in proportion as the body to be dissolved presents a greater surface: on this principle is founded the practice
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of pounding, triturating, and dividing bodies intended to be dissolved. Bergman has even observed, that bodies which are not attacked in considerable masses, become soluble after minute division. Letters on Iceland, p. 421*.

C. The solution of a body constantly produces cold. Advantage has even been taken of this phenomenon to procure artificial cold, much superior to the most rigorous temperature ever observed in our climates. We shall again advert to this principle when we come to treat of the laws of heat.

The principal solvents employed in our operations are water, alcohol, and fire. Bodies submitted to one or the other of these solvents present similar phenomena; they are divided, rarefied, and at last disappear; the most refractory metal melts, is dissipated in vapour, and passes to the state of gas, if a very strong heat be applied to it. This last state forms a complete solution of the metallic substance in the caloric.

The effect of caloric is often united with one of the other solvents, to accomplish a more speedy and abundant solution.

The three solvents here mentioned do not

* Von Troil's Letters, quoted by Bergman: T.

exercise an equal action on all bodies indiscriminately. Skilful chemists have exhibited tables of the dissolving power of these menstruums. We may see, in the Mineralogy of Kirwan, with what care that celebrated chemist has exhibited the degree of solubility of each salt in water. The table of Mr. De Morveau may likewise be consulted on the dissolving power of alcohol. *Journal de Physique*, 1785.

Most authors who have treated of solution have considered it in too mechanical a point of view. Some have supposed sheaths in the solvent, and points in the body dissolved. This absurd and gratuitous supposition has appeared sufficient to account for the action of acids upon bodies. Newton and Gassendi have admitted pores in water, in which salts might insinuate themselves; and have by this means explained why water does not augment in its bulk in proportion to the quantity of salt it takes up. Gassendi has even supposed pores of different forms; and has endeavoured to shew by this means how water saturated with one salt may dissolve others of another kind. Dr. Watson, who has observed the phenomena of solution with the greatest care, has concluded from his numerous experiments; 1. That the water rises in the vessel at the moment of the immersion

sion of the salt. 2. That it falls during the solution. 3. That it rises after the solution above the original level. The two last effects seem to me to arise from the change of temperature which the liquor undergoes. The refrigeration arising from the solution must diminish the volume of the solvent; but it ought to return to its first state as soon as the dissolution is finished. The tables of Dr. Watson respecting these phenomena, and the specific gravity of water saturated with different salts, may be consulted in the *Journal de Physique*, vol. xiii. p. 62*.

III. As the peculiar affinities of bodies to each other are various, the constituent principles may be easily disengaged by other substances; and it is upon this consideration that the action of all the re-agents employed by chemistry in its analysis is founded. Sometimes the chemist displaces certain principles, which he can in that state examine more accurately, because insulated, and disengaged from all their combinations. It frequently happens that the re-agent made use of combines with some principle of the body analysed; and a compound arises, whose characters indicate

* Or in the fifth vol. of his *Chemical Essays*, T.

to us the nature of the principle which has thus entered into combination, because the combinations of the principal re-agents with various bases are well known. It likewise frequently happens that the re-agent made use of is itself decomposed, which circumstance renders the phenomena and the products more complicated; but we are enabled from the nature of these products to form a judgment of the component parts of the body analysed. This last fact was little attended to by the ancient chemists; and this is one of the principal defects of the labours of Stahl, who has referred most of those phenomena to the bodies which he submitted to analysis, which in reality arose only from the decomposition of the re-agents employed in his operations.

SECTION III.

Concerning the Method of Proceeding
which the Chemist ought to follow in
the Study of the various Bodies pre-
sented to us by Nature.

THE progress made in any science de-
pends upon the solidity of those princi-
ples which form its basis, and upon the method
of studying them. It is not, therefore, to be
wondered at, that chemistry made but little
progress in those times, when the language of
chemists was enigmatical, and when the prin-
ciples of the science were founded only on ana-
logies falsely deduced, or on a few facts ill un-
derstood. In the times which have followed
this epocha, the facts have indeed been more
attended to ; but, instead of suffering them to
speak for themselves, chemists have been de-
sirous of making applications, drawing con-
sequences, and establishing theories. Thus it
was that Stahl, when he first observed that
oil of vitriol and charcoal produced sulphur,
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if he had then confined himself to the simple relation of the fact, would have announced a valuable and eternal truth; but when he concluded that the sulphur was produced by the combination of the inflammable principle of the charcoal with the oil of vitriol, he asserted that which the experiment does not point out: then it was that he proceeded further than the facts warranted; and this first rash step might be a first step towards error. All doctrine, in order to be lasting, ought to consist of the pure and simple expression of facts: but we are almost always governed by our imaginations; we adapt the facts to our manner of seeing them, and thus we are misled by ourselves. The prejudice of self-love afterwards furnishes us with various means to avoid recantation; we exert ourselves to draw our successors into the same paths of error; and it is not till after much time has been lost, after many vain conjectures have been exhibited, and after we have the strongest convictions that it is impossible to bend the nature of things to our caprices and unfounded ideas, that some superior mind disengages itself from the delusion; and returning to experiment, and the nature of things, suffers himself to be led no further than he is authorized by these to proceed.

We may affirm to the honour of some of our cotemporaries, that facts are at present discussed by a much severer logic ; and it is to this vigorous method of investigation and discussion that we are indebted for the rapid progress of chemistry. It is in consequence of this dialectic march that we have at length arrived to the practice of attending to all the principles which are combined or disengaged in the operations of nature and art. We keep an account of all the circumstances which have a more or less considerable influence on the results, and we deduce simple and natural consequences from the whole of the facts ; by which means we create a science as strict in its principles as sublime in its applications.

This then is the moment to draw out a faithful sketch of the actual state of chemistry, and to collect in the numerous writings of modern chemists every thing which may serve to lay the foundation of this beautiful science.

Not many years ago, it was possible to present, in a few words, the whole of our knowledge of chemistry. It was sufficient, at that time, to point out the methods of performing pharmaceutical operations ; the processes of the arts were almost all enveloped in darkness, the phenomena of nature were all enigmatical ;
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and it is only since this veil has begun to be removed that we have beheld the development of a collection of facts and researches referable to general principles, and forming a science entirely new. Then it was that a number of men of genius reviewed the whole, and attended to the improvement of chemical knowledge. Every step in their progress brought them nearer to the truth; and in a few years we have beheld a perspicuous doctrine arise out of the ancient chaos. Every event has appeared conformable to the laws they established; and the phenomena of art and nature are now explained with equal facility.

But in order to advance with speed in the career which has been thus opened, it is necessary to explain certain principles, according to which we may direct our steps.

In the first place, I think it proper to avoid that tedious custom which subjects the beginner in any science to the painful task of collecting all the opinions of various philosophers before he decides for himself. In reality, facts belong to all times, and are as unchangeable as nature herself, whose language they are. But the consequences deduced from them must vary according to the state of our acquired knowledge. It is eternally true, for example, that the com-

combustion of sulphur affords the sulphuric acid. It was believed, for a certain time, that this acid was contained in the sulphur; but our discoveries on the combustion of bodies ought to have led us to the deduction of a very different theory from that which presented itself to the earlier chemists. We ought, therefore, to attach ourselves principally to facts; or rather we ought to attach ourselves to the facts only, because the explanation which is given of them at remote times is very seldom suited to the present state of our knowledge.

The numerous facts with which chemistry has been successively enriched form the first embarrassment of the student who is desirous of acquiring the elements of this science. In fact, what are the elements of science? The clear, simple and accurate enunciation of those truths which form its basis. It is necessary, therefore, for the full accomplishment of this purpose, to analyse all the facts, and to exhibit a faithful and clear abridgment: but this method is impracticable on account of the numerous details, and the infinite number of discussions, into which it would lead us. The only proceeding, therefore, which appears to me to be practicable, is to exhibit the most decisive experiments, those which are the least contest-
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ed, and to neglect those which are doubtful or inconclusive: for one experiment, well made, establishes a truth as incontestably as a thousand equally averred.

When a proposition is found to be supported by suspicious, or contested facts, when opposite theories are built upon contradictory experiments, we must have the courage to discuss them, to repeat them, and to acquire a certainty of the truth by our own endeavours. But when this method of conviction is out of our power, we ought to weigh the degree of confidence which the defenders of the opposite facts are entitled to; to examine whether analogous facts do not lead us to adopt certain results; after which it becomes us to give our opinion with that modesty and circumspection, suitable to the greater or less degree of probability annexed to each opinion.

But when any doctrine appears to us to be established on experiments of sufficient validity, it then remains to be applied to the phenomena of nature and art. This, in my opinion, is the most certain touchstone to distinguish true principles from those which are without foundation. And when I observe that all the phenomena of nature unite, and conform themselves, as it were, to any theory, I conclude that
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this theory is the expression and the language of truth. When, for example, I behold that a plant can be supported by pure water alone, that metals are calcinable, that acids are formed in the bowels of the earth, have I not a right to conclude that the water is decomposed? and do not the chemical facts which in our laboratories afford a testimony of its decomposition—do not these acquire a new force by the observation of the preceding phenomena? I conclude, therefore, that we ought to make a point of uniting these two kinds of proofs: and a principle deduced from experiment is not, in my opinion, demonstrable, until I see that it may with facility be applied to the phenomena of art and nature. Hence, if I find myself in a state of hesitation between opposite systems, I will decide in favour of that whose principles and experiments adapt themselves naturally, and without force, to the greatest number of phenomena. I will always distrust a single fact, which is applicable to no conclusion; and I will consider it as false, if it be in opposition to the phenomena which nature presents to us.

It appears to me likewise that he who professes to study, or even to teach chemistry, ought not to endeavour to arrive at or exhibit the whole which has been done in each department,

ment, or to follow the tedious progress of the human mind from the origin of a discovery to the present time. This fastidious erudition is fatiguing to the learner; and these digressions ought in no case to be admitted in the enunciation of science, excepting when the historical details afford interesting facts, or lead us by uninterrupted degrees to the present state of our knowledge. It rarely happens, however, that this kind of researches, this genealogy of science, affords us such characters; and it ought no more to be admitted, in general, that an elementary writer should bring together and discuss every thing which has been done in a science, than that he who undertakes to direct a traveller should previously enter into a long dissertation on all the roads which have been successively made, and on those which still exist, before he should point out the best and shortest way to arrive at the end of his journey. It may, perhaps, be said of the history of science, and more especially that of chemistry, that it resembles the histories of nations. It seldom affords any light respecting the present situation of affairs; exhibits many fables concerning past times; induces a necessity of entering into discussions upon the circumstances that pass in review; and supposes a mass of
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extraneous knowledge acquired on the part of the reader, which is independent of the purpose aimed at in the study of the elements of chemistry.

When these general principles, respecting the study of chemistry, are once well established, we may afterwards proceed in the chemical examination of bodies in two ways: we may either proceed from the simple to the compound, or we may descend from the compound to the simple. Both these methods have their inconveniences; but the greatest, no doubt, which is found in following the first method is, that, by beginning with the simplest bodies, we present substances to the consideration of the learner which nature very seldom exhibits in such a state of nakedness and simplicity; and we are forced to conceal the series of operations which have been employed to divest these substances from their combinations, and reduce them to the elementary state. On the other hand, if we present bodies to the view of the learner such as they are, it is difficult to succeed in an accurate knowledge of them; because their mutual action, and in general most of their phenomena, cannot be understood without the previous and accurate knowledge of

of their constituent principles, since it is upon these alone that they depend.

After having maturely considered the advantages and inconveniences of each method, we give the preference to the first. We shall therefore begin by giving an account of the several bodies in their most elementary state, or reduced to that term beyond which analysis can effect nothing; and, when we shall have explained their various properties, we will combine these bodies with each other, which will afford a class of simple compounds: and hence we shall rise by degrees to the knowledge of bodies, and the most complicated phenomena. We shall be careful, in any examination of the several bodies to which we shall direct our researches, to proceed from known to unknown; and our first attention shall be directed to elementary substances. But as it is impossible, at one and the same time, to treat of all those substances which the present state of our knowledge obliges us to consider as elementary, we shall confine ourselves to the exhibition of such as are of the greatest importance in the phenomena of the globe we inhabit, such as are almost universally spread over its surface, and such as enter as principles into the composition of the re-agents most frequently employed in
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our operations; such, in a word, as we continually find in the examination and analysis of the component parts of the globe. Light, heat, sulphur, and carbone are of this number. Light modifies all our operations, and most powerfully contributes to the production of all the phenomena which appertain to bodies either living or inanimate. Heat, distributed after an unequal proportion among all the bodies of this universe, establishes their various degrees of consistence and fixity; and is one of the great means which art and nature employ to divide and volatilize bodies, to weaken their force or adhesion, and by that means prepare them for analysis. Sulphur exists in the products of the three kingdoms; it forms the radical of one of the best known, and most generally employed, acids; it exhibits interesting combinations with most simple substances; and, under these several points of view, it is one of the substances the most necessary to be known in the first steps of chemical science. The same may be said of carbone; it is the most abundant fixed product found in vegetables and animals. Analysis has discovered it in some mineral substances. Its combination with oxygene is so common in bodies, and in the operations of art and nature, that there are
scarcely

scarcely any phenomena which do not present it to our view, and which consequently require the knowledge of its properties. From all these reasons it appears to us, that for the advancement of chemistry it is necessary our first proceeding should be founded on the knowledge of these substances; and that we should not direct our attention to other simple or elementary substances, accordingly as they present themselves.

SECTION IV.

Concerning Simple or Elementary Substances.

IF we cast an eye over the systems which have been successively formed by philosophers relative to the number and nature of the elements, we shall be astonished at the prodigious variety which prevails in their manner of thinking. In the earlier times, every one seems to have taken his own imagination for his guide; and we find no reasonable system until the time when Aristotle and Empedocles acknowledged as elements, Air, Water, Earth, and Fire. Their opinion has been well received for many ages; and it must be confessed that it is calculated to seduce the mind. There are, in fact, enormous masses, and inexhaustible stores, that present themselves to our view, of these four principles, to which the destruction or decomposition of bodies appeared to refer all the several component parts which formation or creation had taken from them. The authority of all those great men who had adopted this system, and the analysis of bodies which presented

sented only these four principles, afforded sufficient grounds for admitting this doctrine.

But as soon as chemistry had advanced so far as to discover the principles of bodies, the professors of that science presumed to mark the number, nature, and character of the elements; and every substance that was unalterable by the chemical methods of decomposition, was considered by them as a simple or elementary principle. By thus taking the limits of analysis as the term for indicating the elements, the number and the nature of these must vary according to the revolutions and the progress of chemistry. This has accordingly happened, as may be seen by consulting all the authors who have written on this subject, from the time of Paracelsus to the present day. But it must be confessed that it is no small degree of rashness, to assume the extent of the power of the artist as a limit for that of the Creator, and to imagine that the state of our acquisitions is a state of perfect knowledge.

The denomination of Elements ought therefore to be effaced from a chemical nomenclature, or at least it ought not to be used but as an expression denoting the last term of our analytical results; and it is always in this sense that we shall use the word.

CHAP. I.

Concerning Fire.

THE principal agent employed by nature to balance the power and natural effect of attraction, is fire. By the natural effect of attraction we should possess none but solid and compact bodies; but the caloric unequally dispersed in bodies tends incessantly to destroy this adhesion of the particles; and it is to this principle that we are indebted for the varieties of consistence under which bodies present themselves to our observation. The various substances that compose this universe are therefore subjected, on the one hand, to a general law which tends to bring them together; and, on the other hand, to a powerful agent which tends to remove them from each other: it is upon the respective energy of these two forces that the consistence of all bodies depends. When the affinity prevails, they are in the solid state; when the caloric is most powerful, they are in the state of gas; and the liquid state appears to be the point of the equilibrium between these two powers.

It is therefore essentially necessary to treat of fire, since it acts so leading a part in this universe;

verse; and because it is impossible to treat of any substance whatever without attending to the influence of this agent.

There are two things to be considered in fire—heat and light.

These two principles, which have been very often confounded, appear to be very distinct in their own nature; because they are scarcely ever proportional to each other, and because each can exist without the other.

The most usual acceptation of the word Fire comprehends heat and light; and its principal phenomena must have been known for a long time. The discovery of fire must have been nearly as ancient as the human species upon this globe. The shock of two flints, the action of meteors, or the effect of volcanoes, must have afforded the earliest idea of it; and it is very astonishing that the inhabitants of the Marlan Islands were not acquainted with its effects before the invasion of the Spaniards. These islanders, who became acquainted with this terrible element only in consequence of its ravages, considered it at first as a malevolent being which attached itself to all beings, and devoured them.—See the Abbé Raynal's *Histoire Philosophique*, &c.

The effects of fire are perhaps the most astonishing

nishing of any which nature exhibits ; and we ought not to be surpris'd that the ancients considered it as an intermediate being between spirit and matter, and have built the beautiful fable of Prometheus upon its origin. We have had the happiness, in our time, to acquire well-founded and extensive ideas respecting this agent, which we shall proceed to develop in the two following articles.

A R T I C L E I.

Concerning Caloric and Heat.

When a metal or a liquid is heated, these bodies are dilated in every direction, are reduced to vapour, and at last become invisible when the most powerful heat is applied to them.

Bodies which possess the principle of heat, part with it more or less readily. If we attentively observe a body during its cooling, a slight movement of undulation will be perceived in the surrounding air ; an effect which may be compared to the phenomenon exhibited upon the mixture of two liquors of unequal density and weight.

It is difficult to conceive this phenomenon without admitting of a peculiar fluid, which passes first from the body which heats to that
which

which is heated, combines with the latter, produces the effects we have spoken of, and afterwards escapes to unite with other bodies, according to its affinities, and the law of equilibrium, to which all bodies tend.

This fluid of heat, which we call Caloric, is contained in greater or less quantities in bodies, according to the greater or less degrees of affinity existing between it and them.

Various means may be employed to displace or disengage the caloric. The first is by the method of affinities : for example, water poured upon the sulphuric acid expels the heat, and takes its place ; and while there is a disengagement of heat, the volume of the mixture does not increase in proportion to the bulk of the two substances mixed. This shews that penetration takes place, which cannot be explained but by admitting that the integrant parts of the water take the place of the caloric, in proportion as it is dissipated.—The second method of precipitating caloric, is by friction and compression. In this case it is expressed or squeezed out, in the same manner as water from a sponge. In reality, the whole of the heat which may be produced by friction, is not afforded by the body itself ; because, in proportion as the interior heat is developed, the external air acts

upon the body, calcines or inflames it, and itself gives out heat during its fixation. Fermentation, and in general every operation which changes the nature of bodies, may disengage caloric, because the new compound may demand and receive a greater or less quantity. Hence it is that chemical operations produce sometimes cold, and sometimes heat.

Let us now examine the form under which caloric presents itself.

This fluid is disengaged either in a state of liberty, or in a state of combination.

In the first case, the caloric always endeavours to obtain an equilibrium; not that it is distributed equally among all bodies, but it is dispersed among them according to the degrees of its affinity. Whence it follows, that the circumambient bodies receive and retain a quantity more or less considerable. Metals are easily penetrated by this fluid, and transmit it with equal facility; wood and animal substances receive it to the degree of combustion; liquids, until they are reduced to vapour. Ice alone absorbs all the heat communicated to it, without giving it out to other bodies until it has acquired the fluid state*.

* The ingenious author has inadvertently been guilty of an oversight. Not only ice, but all other bodies, absorb heat during liquefaction, as he himself shews hereafter. T.

The

The degree of heat can be appreciated only by its effects: and the instruments which have been successively invented to calculate it, and are known by the names of thermometers, pyrometers, &c. have been applied to the strict determination of the several phenomena exhibited in consequence of the absorption of caloric in various bodies.

The dilatation of fluids, or of metals in the fluid state, by the several degrees of heat, has been long measured by thermometers formed of glass; but this very fusible substance can only be used to ascertain degrees of heat inferior to that which renders the glass itself fluid.

Several means have been successively proposed for calculating the higher degrees of heat. Mr. Leidenfrost has proved that the hotter a metal is, the more slowly will drops of water evaporate from its surface; and he has proposed this principle for the construction of pyrometers. A drop of water in an iron spoon, heated to the degree of boiling water, evaporates in one second; a similar drop, poured on melted lead, is dissipated in six or seven seconds; and upon red-hot iron in thirty. Mr. Ziegler, in his *Specimen de Digestore Papini*, has found that 89 seconds were required to evaporate a drop of water at 520 degrees of Fahrenheit; and that

one-second is sufficient at the 300th degree. This phenomenon, which is more interesting to chemistry than pyrometry, to which it will always afford results little susceptible of rigorous calculation, appears to me to depend upon the adhesion and decomposition of the water upon the metal.

The most accurate pyrometer we are acquainted with, is that which was presented to the Royal Society of London by Mr. Wedgwood. It is constructed upon the principle, that the purest clay shrinks in the fire in proportion to the heat applied to it. This pyrometer consists of two parts; one called the gauge, which serves to measure the degrees of diminution or shrinking; the other contains the simple pieces of pure clay, which are called thermometer pieces.

The gauge is formed of a plate of baked earth, upon which are applied two rulers or straight pieces of the same substance. These rulers, being perfectly straight and even, are placed at the distance of half an inch from each other at one of their ends, and three-tenths of an inch at the other. For greater convenience, the gauge is divided into two parts, and the two pieces are placed endways when required to be used. The length of this rule is divided into

240 equal parts, of which each represents one-tenth of an inch*. To form the thermometer pieces, the earth is sifted with the greatest attention, after which it is mixed with water, and the paste thrust through an iron tube, which gives it a cylindrical form, to be cut afterwards into pieces of a proper size. When the pieces are dry, they must be presented to the gauge, where they ought to fit at the place of 0 on the scale. If by inadvertence of the workmen any piece penetrates to one or two degrees further, this degree is marked on its flat surface, and requires to be deducted when the piece is used in the admeasurement of heat. The pieces thus adjusted are baked in a furnace to a red heat, to give them the consistence necessary for carriage. The heat employed in this part of the process is usually about six degrees, and the pieces are diminished more or less; but this is of no consequence when they come to be submitted to a superior degree of heat; and if it should happen that an inferior degree of heat is required to be measured, unbaked pieces are to be used, which are preserved in sheaths or cases to avoid friction.

When this pyrometer is to be used, one of

* This is, in fact, the twelve-hundredth of an inch in the width, according to the dimensions here given. T.

the pieces is exposed in the fire-place, whose heat is required to be determined; and when it has acquired the whole intensity, it is taken out, and suffered to cool, or for greater speed it is plunged in water; after which it is presented to the gauge, and its degree of contraction easily determined. Mr. Wedgwood has given us the result of several experiments made with his pyrometer, opposite to which he has placed the correspondent degrees of Fahrenheit.

	Pyrometer of Wedgwood.	Thermometer of Fahrenheit.
Red heat visible by the light	0	1077
Brass melts at	21	1857
Swedish copper melts at	27	4587
Pure silver melts at	28	4717
Pure gold melts at	32	5237
The heat of bars of iron raised { small bar	90	12777
to welding { large bar	95	13427
The greatest heat producible in a smith's forge	125	17327
Cast iron melts at	130	17977
The greatest heat of a wind furnace of eight inches square	160	21877

These various thermometers are not applicable to all cases. We cannot, for example, calculate with strictness the heat which escapes from living bodies, or determine with precision the temperature of any substance. But Messrs. De la Place and Lavoisier (Acad. des Sciences, 1780) have invented an apparatus which appears to leave nothing further to be desired. It

is.

is constructed upon the principle that ice absorbs all the heat communicated to it, without communicating it to other bodies until the whole is melted; so that from hence we may calculate the degrees of heat communicated, by the quantity of ice which is melted. It was necessary, in order to afford strict results, to discover the means of causing the ice to absorb all the heat disengaged from the bodies under examination, and to cover it from the action of every other substance which might facilitate its fusion; and, lastly, to collect with great care the water produced by the fusion.

The apparatus constructed by these two celebrated academicians for this purpose, consists of three circular vessels nearly inscribed in each other; so that three capacities are produced. The interior space or capacity is formed by an iron grating, upon supports of the same metal. Here it is that the bodies subjected to experiment are placed. The upper part of this cavity is closed by means of a cover. The middle space, next to this, is designed to contain the ice which surrounds the interior compartment. This ice is supported and retained by a grate, upon which a cloth is spread. In proportion as the ice melts, the water flows through the grate and the cloth, and is collected in a
vessel

vessel placed beneath. Lastly, the external space or compartment of the apparatus contains ice intended to prevent the effect of the external heat of the atmosphere.

To use this excellent machine, the middle or second space is filled with pounded ice, as is likewise the cover of the internal sphere; the same thing is done with regard to the external space, as well as to the general covering of the whole machine: the interior ice is suffered to drain; and, when it ceases to afford water, the covering of the internal space is raised, to introduce the body upon which the experiment is intended to be made. Immediately after this introduction, the covering is put on, and the whole apparatus remains untouched until the included body has acquired the temperature of 0, or the freezing temperature of water, which is the common temperature of the internal capacity. The quantity of water afforded by the melting of the ice is then weighed; and this is an accurate measure of the heat disengaged from the body, because the fusion of the ice is the effect of this heat only. Experiments of this kind last fifteen, eighteen, or twenty hours.

It is of great consequence, that in this machine there should be no communication between

tween the middle, or second, and the external space.

It is likewise necessary that the air of the apartment should not be lower than 0, because the interior ice would then receive a degree of cold lower than that temperature.

Specific heat is merely the proportional quantity of heat necessary to raise bodies of equal mass to the same number of degrees of temperature : so that, when the specific heat of a solid body is required, its temperature must be elevated a certain number of degrees, at which instant it must be placed in the internal sphere, and there left until its temperature is reduced to 0. The water is then collected, and this quantity divided by the product of the mass of the body ; and the number of degrees of its original temperature above 0, will be proportional to its specific heat.

With regard to fluids, they are inclosed in vessels whose heat has been previously determined. The operation is then the same as for solids ; excepting that the quantity of water afforded must be diminished by a deduction of that quantity which has been melted by the heat of the vessel.

If it be required to determine the heat which is disengaged during the combination of various substances,

substances, they must be all reduced, as well as their containing vessels, to the temperature of 0. The mixture must then be placed in the internal sphere; and the quantity of water collected is the measure of the disengaged heat.

In order to determine the heat of combustion and respiration, as the renewal of air is indispensable in these two operations, it is necessary to establish a communication between the internal part of the sphere and the surrounding atmosphere; and in order that the introduction of fresh air may not cause any perceptible error, these experiments ought to be made at a temperature little differing from 0; or at least the air which is introduced must previously be brought to this temperature.

To determine the specific heat of any gas, it is necessary to establish a current through the internal part of the sphere, and to place two thermometers, one at the place of introduction, and the other at the place of escape. By comparison of the temperatures exhibited by these two instruments, a judgment is formed of the heat absorbed, and the melted ice is measured.

An excellent memoir of Messrs. De la Place and Lavoisier may be consulted for the results of the experiments they have made. The present extract contains only a short account of their valuable labours.

The

The various means made use of for the ad-measurement of heat, are founded on the general principle, that different bodies absorb heat in greater or less quantities. If this fact were not generally admitted, it might be established on the three following facts. Dr. Franklin having exposed two small pieces of cloth, of the same texture but of different colours, upon the surface of snow, perceived a few hours afterwards, that the red cloth was buried in the snow, while the other which was white had not suffered any depression*. M. de Saussure observes, that the peasants of the mountains of Switzerland are careful to spread a black earth over the surface of grounds covered with snow, when they are desirous of melting it to sow their seed. So likewise children burn a black hat in the focus of a small lens which would scarcely heat a white one.

Such nearly are the phenomena of heat when it is disengaged in a state of liberty. Let us now contemplate those which it presents when it escapes from a state of combination.

Heat is sometimes disengaged in a state of simple mixture, as in the phenomena of vapours, sublimations, &c. If heat be applied to water, these two fluids will unite, and the mix-

* They were exposed to the rays of the sun. T.

ture will be dissipated in the atmosphere; but it would be an abuse of words to call so weak an union by the name of combination: for, as soon as the heat becomes in a situation to combine with other bodies, it abandons the water, which returns to a liquid state. This body, during evaporation, continually carries with it a portion of heat; and hence, perhaps, result the advantages of transpiration, perspiration, &c.

But heat very frequently contracts a true chemical union with the bodies which it volatilizes: this combination is even so perfect, that the heat is not perceptible, but it is neutralized by the body with which it is combined. It is then called latent heat, *calor latens*.

The several cases in which heat enters into combination, and passes to the state of latent heat, may be reduced to the two following principles:

The first principle.—Every body which passes from the solid to the liquid state, absorbs a portion of heat, which is no longer sensible to the thermometer, but exists in a true state of combination.

The academicians of Florence filled a vessel with pounded ice, and plunged a thermometer in it, which descended to 0. The vessel was then immersed in boiling water, and the thermometer

mometer did not rise during the whole time of the liquefaction of the ice. The fusion of ice therefore absorbs heat.

Mr. Wilcke poured a pound of water, heated to the 60th degree of Reaumur, upon a pound of ice. The melted mixture possessed the temperature of 0. Sixty degrees of heat had therefore entered into combination.

The chevalier Laudriani has shewn that the fusion of metals, of sulphur, of phosphorus, of alum, of nitre, &c. absorbs heat.

Cold is produced in the dissolution of all the (crystallized) salts.

Reaumur made a series of very interesting experiments on this subject, which confirm those of Boyle. Fahrenheit caused the thermometer to descend to forty degrees, by melting ice by strong nitrous acid. But the most astonishing experiments are those made by Messrs. Thomas Beddoes*, physician, and Walker, apothecary at Oxford, and inserted in the *Philosophical Transactions* for the year 1787†. The mixtures which produced the greatest degrees of cold are,

* It does not appear that Dr. Beddoes either had or pretends to have any other share in the experiments of Mr. Walker, than that of having transmitted them to the Royal Society. T.

† Also in the subsequent volumes.

1. Eleven parts of muriate of ammoniac, or common sal ammoniac; ten parts of nitrate of pot-ash, or common nitre; sixteen parts of sulphate of soda, or Glauber's salt; with thirty-two parts by weight of water: the two first salts should be dry, and in powder. 2. The nitric acid, muriate of ammoniac, and sulphate of soda, lowered the thermometer to eight degrees under 0. Mr. Walker has frozen mercury without using either ice or snow.

It is therefore an incontrovertible principle, that all bodies which pass from the solid to the liquid state, absorb heat, and retain it in so accurate a combination as to afford no sign of its presence. The heat is therefore fixed, neutralized, or latent.

The second principle.—All bodies, by passing from the solid or fluid state to the æri-form state, absorb heat, which becomes latent; and it is by virtue of this heat that such bodies are placed and maintained in that state.

On this principle is founded the process used in China, India, Persia, and Egypt, to cool liquors used for drink.

The water intended for this purpose is put into very porous vessels, and exposed to the sun, or to a current of warm air, to cool the fluid contained within them.

It

It is by similar means that cool drink is obtained in the long journeys of the caravans. Interesting details on this subject may be seen in the Travels of Chardin, vol. iii. 1723; Tavernier's Voyages, vol. i. edit. 1738; Paul Lucas's Voyages, vol. ii. edit. 1724; and also in the Mundus Subterraneus of P. Kircher, lib. vi. sec. 2. cap. 2.

We may conclude from the experiments of Mr. Richmann, made in 1747, and inserted in the first volume of the Imperial Academy of Petersburg, 1. That a thermometer taken out of water, and exposed to the air, always descends, even when its temperature is equal or superior to that of the water. 2. That it afterwards rises, until that it has acquired the temperature of the atmosphere. 3. That the time of descending is less than that which it employs to rise again. 4. That when the thermometer, withdrawn from the water, has arisen to the common temperature, its bulb is dry; but that it continues wet during the whole time of its standing beneath this common temperature.

To these consequences we will add others deduced from several curious experiments by the celebrated Cullen. 1. A thermometer suspended in the receiver of the air pump, descends two or three degrees during the time of exhaustion,

exhaustion, and afterwards rises to the temperature of the vacuum. 2. A thermometer plunged in alcohol, in the receiver of the air pump, always descends, and the lower in proportion as the bubbles are stronger which issue from the alcohol; if it be withdrawn from this liquor, and suspended wet beneath the receiver, it falls eight or ten degrees while the air is pumping out.

It is well known that if the ball of a thermometer be wrapped in fine linen, and kept moist by sprinkling with ether, and the evaporation be facilitated by agitation in the air, the thermometer will descend to 0.

The immortal Franklin has proved, in his own person, that when the body perspires strongly, it is less heated than surrounding bodies, and that perspiration always produces a certain degree of coldness.—See his Letter to Dr. Lind.

The great number of labourers in the burning heats of our climate support themselves only by virtue of a copious perspiration, the fluid for which they replenish by drinking plentifully. The workmen employed in glass-houses, foundries, &c. often live in a medium hotter than their bodies, the natural temperature of which is equalized and moderated by perspiration.

If evaporation be increased by agitation of
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the air, the refrigeration is the greater. Hence the use of fans, ventilators, &c. which, though intended to give motion to warm air, afford likewise the virtue of cooling by facilitating and favouring evaporation.

Warm and dry air is best suited to form a refreshing current, because it is more calculated to dissolve and absorb humidity; moist air is less proper, because it is already saturated.—Hence the necessity of frequently renewing the air to preserve the coolness of our apartments.

These principles have a nearer relation to medicine than is generally supposed. We find that almost all fevers end in perspirations, which, beside the advantage of expelling the morbid matter, possess likewise that of carrying off the matter of heat, and restoring the body to its common temperature. The physician who is desirous of moderating the excess of heat in the body of a patient, ought to maintain the air in that disposition which is most suitable to his views.

The use of volatile alkali is universally acknowledged to be of advantage in burns, the tooth-ach, &c. May not these effects be attributed to the volatility of this substance, which quickly combining with heat, carries it off, and leaves an impression of cold?—Ether is a sove-

reign remedy for the colic. Does not its virtue depend on the same principles?

The heat which has entered into combination with bodies during their transition from the solid to the liquid state, or from this last to the æriform state, may be again exhibited by causing these substances to return again to the states of liquefaction or solidity. In a word, every substance which passes from the liquid to the solid state, suffers its latent heat to escape, which at this instant becomes free or thermometrical heat.

The celebrated Fahrenheit, in the year 1724, having left water exposed to a colder temperature than that of ice, the water remained fluid: but it congealed by agitation; and the thermometer, which marked several degrees beneath the freezing point, suddenly rose to that temperature. Mr. Treiwald mentions a similar fact in the Transactions; and Mr. De Ratte made the same observation at Montpelier.

Mr. Baumé has shewn, in his enquiries and experiments relating to several singular phenomena exhibited by water, at the instant of its congelation, that several degrees of heat are always developed at that instant.

1. Gaseous substances are maintained in the æriform state merely by the heat which is combined

bined with them; and when to these substances, thus dissolved in caloric, another body is presented, to which they have a very strong affinity, they abandon their heat to unite with this last substance; and the caloric, thus expelled or disengaged, appears under the form of free or thermometrical heat. This disengagement of heat, by the concretion or fixation of gaseous substances, was observed by the celebrated Scheele, as may be seen in the valuable experiments which form the basis of his Treatise on Air and Fire. Since the time of this great man, rigorous calculations have been made of the quantity of latent heat existing in each of these gases: we are indebted to Messrs. Black, Crawford, Wilcke, De la Place, Lavoisier, &c. for many excellent researches on this subject.

ARTICLE II.

Concerning Light.

It appears that Light is transmitted to our eyes by a peculiar fluid which occupies the interval between us and visible bodies.

Does this fluid arrive directly from the Sun by successive emissions or eradiations? or is it

a peculiar fluid distributed through space, and put in action by the Sun's rotary motion, or by any other cause? I shall not enter into any discussion upon this subject, but shall confine myself to point out the phenomena.

A. The motion of light is so rapid, that it passes through nearly eighty thousand leagues in a second.

B. The elasticity of the rays of light is such, that the angle of reflection is equal to the angle of incidence.

C. The fluid of light is ponderous ; for if a ray of light be received through a hole in a window-shutter, and the blade of a knife be presented to it, the ray is diverted from a right line, and is inflected towards the body. This circumstance shews that it obeys the law of attraction, and sufficiently authorises us to class it among other bodies of this nature.

D. The great Newton succeeded in decomposing the solar light into seven primitive rays, which present themselves in the following order: red, orange, yellow, green, blue, indigo, violet. Dyes present us with only three colours, which are red, blue, and yellow ; the combinations and proportions of these three principles form all the shades of colour with which the arts are enriched. Philosophers have maintained that
among

among the solar rays there are three primitive colours.—See *Les Recherches de M. Marat*.

All natural bodies may be considered as prisms which decompose or rather divide the light. Some reflect the rays without producing any change, and these are white; others absorb them all, and cause absolute blackness: the greater or less affinity of the several rays with various bodies, and perhaps likewise the disposition of the pores, is no doubt the cause that, when a pencil falls upon a body, some rays enter into combination, while others are reflected; and it is this which affords the diversity of colours, and the prodigious variety of shades under which bodies appear to our eyes.

We can no longer confine ourselves to consider light as a merely physical substance; the chemist perceives its influence in most of his operations, and finds it necessary to attend to its action, which modifies his results; and its effects are no less evident in the various phenomena of nature, than in the experiments performed in our laboratories.

We see that vegetation cannot take place without light. Plants deprived of this fluid become pale; and when in hot-houses the light comes to them from one part only, the vegetables incline towards the aperture, as if to shew the necessity of this beneficial fluid.

Without

Without the influence of light, vegetables would exhibit but one lifeless colour; they are deprived of their beautiful shades by the interception of this luminous fluid. On these principles, celery, endive, and other plants, are bleached.

Vegetables are not only indebted to the light for their colour, but likewise for their smell, taste, combustibility, maturity, and the resinous principle, which equally depend upon this fluid. Hence it is, no doubt, that aromatic substances, resins, and volatile oils, are the inheritance of southern climates, where the light is more pure, constant, and intense.

We see, likewise, that the influence of light is evident in other beings: for, as Mr. Dorthes has observed, worms and grubs, which live in the earth or in wood, are of a whitish colour. The birds and flying insects of the night are likewise distinguishable from those of the day by the want of brilliancy of colour; and the difference is equally marked between those of the north and of the south.

A very astonishing property of light upon the vegetable kingdom is, that when vegetables are exposed to open day-light, or to the sun's rays, they emit vital air. We shall again attend to all these phenomena when we come to treat of the analysis of vegetables.

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The fine experiments of Scheele and Berthollet have shewn that the absence or presence of light has an astonishing effect upon the result of chemical experiments. Light disengages vital air from several fluids, such as the nitric acid, the oxygenated marine acid, &c. It reduces the oxides or calces of gold, silver, &c. It changes the nature of oxygenated muriates, according to the observations of Mr. Berthollet. Light likewise determines the phenomena of vegetation exhibited by saline solutions, as I have shewn. From all which circumstances it is evident that we ought to attend to the effect of this agent in almost all our operations.

“Organization, sensation, spontaneous motion, and life, exist only at the surface of the earth, and in places exposed to light: we might affirm that the flame of Prometheus's torch was the expression of a philosophical truth which did not escape the ancients. Without light, nature was lifeless, inanimate, and dead: a benevolent God, by producing light, has spread organization, sensation, and thought over the surface of the earth.”—*Elementary Treatise of Chemistry* by Mr. Lavoisier.

We ought not to confound the solar light with the light of our furnaces, the light of these

these has, as I am convinced, very evident effects in certain phenomena; but these effects are slow, and scarcely comparable with those of the solar light.

Although heat often accompanies light, the phenomena we have mentioned cannot be attributed to mere heat. Heat may indeed modify them where it exists, but most assuredly it cannot produce them.

CHAP. II.

Concerning Sulphur.

WE are obliged to place Sulphur among the elements, though our predecessors pretended to have determined its constituent principles. This proceeding would appear to be retrograde, if it were not evident that the correction of mistakes is a real advancement in science.

The ancients used the word sulphur to denote every combustible and inflammable substance. Accordingly we find, in all their writings, the expressions of sulphur of metals, sulphur of animals, sulphur of vegetables, &c.

Stahl assigneth a determinate value to the denomination of Sulphur; and since the time of
this

Origin of Sulphur.

this celebrated chemist we have confined the name to denote a body of an orange-yellow colour, dry, brittle, capable of burning with a blue flame, and exhaling a penetrating odour during combustion : when rubbed, it becomes electric ; and by a light pressure in the hand it cracks, and becomes reduced to powder.

It appears that sulphur is formed by the decomposition of vegetables and animals. It has been found on the walls of necessary-houses ; and when the ditch of the Port St. Antoine, at Paris, was cleared, a considerable quantity was collected, which was mixed with the decayed remains of vegetable and animal substances, that had filled the ancient ditches, and there putrefied.

Mr. Deyeux has likewise proved, that sulphur exists naturally in certain plants, such as *patientia*, *cochlearia*, &c. His processes for extracting it consist in—1. The washed root must be reduced by rasping into a fine pulp ; this must be washed in cold water, and passed through a sieve or cloth of an open texture ; the fluid passes in a turbid state, and deposits a precipitate, which when dried proves the existence of sulphur. 2. The pulp may be boiled, and the scum afforded by the ebullition afterwards dried : this scum contains sulphur. Several

Processes for extracting

veral species of rumex, confounded under the name of Patience, do not contain sulphur. I have obtained it from the rumex patientia L. which grows on the mountains Cevennes, and is the same which is used at Paris. M. Le Veillard obtained sulphur by suffering vegetable substances to putrefy in well-water. Sulphur is abundantly contained in coal mines; it is found in combination with certain metals; it appears almost always where vegetable decomposition takes place; it forms the greater part of those pyritous and bituminous schists which occupy the focus of volcanos; it is sublimed in those places where the pyrites are decomposed; it is thrown out by subterraneous fires; and is found in greater or less quantities in volcanic districts. Much has been said concerning showers of sulphur; but it is at present well known that this error has chiefly arisen from the powder of the stamina of the pine, which is carried to great distances. Henckel saw the surface of a marsh entirely covered with this powder.

The known processes for extracting sulphur in the large way, and applying it to the purposes of commerce, consist in disengaging it from the pyrites or sulphures of copper, or of iron, by methods possessing various degrees of simplicity and economy. On this subject, the
Pyritology

Pyritology of Henckel, Macquer's Chemical Dictionary, and the Metallurgical Tracts of Mr. Jars, may be consulted.

In Saxony and Bohemia the ores of sulphur are distilled in earthen tubes disposed in a gallery. The sulphur which is disengaged by the heat passes into receivers placed without, and in which care is taken to keep a sufficient quantity of water.

At Rammelsberg, at St. Bel, &c. large heaps of pyrites are made, which are decomposed by a gentle heat, at first applied to the mass from a stratum of combustible matter upon which it is placed. The heat is afterwards kept up by the action of the pyrites amongst each other. The sulphur which exhales cannot escape laterally; because care is taken to cover the sides with earth. It therefore rises to the summit of the truncated pyramid, where it is collected into small cavities made for that purpose. The heat of this part is sufficient to keep the sulphur in a fluid state; and it is taken out from time to time with ladles.

Almost all the sulphur used in France comes from the Solfatara. This volcanic country every where exhibits marks of the agency of subterraneous fire. The enormous masses of pyrites which are decomposed in the bowels of the earth produce heat, which sublimes part of the sulphur

sulphur through apertures which the fire, and the effort of the vapours, have opened in all parts. The earths and stones which contain sulphur are distilled; and it is the result of this distillation which is called Crude Sulphur.

The crude sulphur is transported into France by the way of Marseilles, where it receives the necessary preparations to render it suitable to various purposes. 1. It is reduced into sticks or rolls, by fusing it, and pouring it into moulds: or, 2. It is formed into flowers of brimstone by subliming it with a gentle heat, and collecting this sulphureous vapour in a very close chamber of considerable extent. This very pure and finely divided sulphur is distinguished by the name of Flowers of Brimstone, or Sublimed Sulphur.

Sulphur enters into fusion by a moderate heat; and if the moment be seized in which the surface congeals, and the liquid sulphur contained beneath that surface be then poured out, the internal cavity will exhibit long needle-formed crystals of an octahedral figure. This process, contrived by the famous Rouelle, has been applied to the crystallization of almost all the metals. Sulphur is found naturally crystallized in Italy, at Conilla near Cadiz, &c. Its usual form is octahedral; but I have seen crystals of sulphur in perfect rhomboids.

Stahl

Stahl thought that he had proved, by analysis and synthesis, that sulphur is formed by the combination of his phlogiston with the sulphuric acid. The happy series of proofs which he has left behind him for the establishment of this opinion, has appeared so complete, that, since the time of this great man, his doctrine has constantly been admitted as founded on absolute proof. This example was even urged as an instance to shew how high a degree of evidence the chemical analysis was capable of affording. But our discoveries respecting gaseous substances have shewn us, that the ancients were necessarily led into error for want of that knowledge. The immense researches of the moderns into the composition of acids, have shewn that these substances are decomposed in a variety of operations; and this revolution in the state of our knowledge must have produced a similar change in our methods of explaining the phenomena. An examination of the principal experiments of Stahl, upon which his doctrine essentially depends, will sufficiently shew the truth of what we have asserted.

If one third part of charcoal, and two thirds of sulphate of pot-ash, or vitriolated tartar, be mixed and fused in a crucible, the product is (liver of sulphur) sulphure of pot-ash. If this sulphure

phure be dissolved in water, and the alkali be engaged by adding a few drops of sulphuric acid, a precipitate is afforded, which consists of true sulphur : "whence," says Stahl, "the sulphur is a combination of phlogiston, or the inflammable principle of the charcoal with the sulphuric acid." The experiment was true, but the consequence is absurd ; because it would follow that the sulphuric acid which was added, must have possessed the property of displacing sulphuric acid united to the alkali*.

If Stahl had more strictly analysed the result or product of this operation, he would have been convinced that it does not contain a particle of sulphuric acid.

If he had been possessed of the power of operating in closed vessels, and of collecting the gaseous substances which are disengaged, he would have obtained a large quantity of carbonic acid, which arises from the combination of the oxygen of the sulphuric acid with charcoal.

* Without pretending, on the present occasion, to dispute either for or against phlogiston, I shall observe that this argument is one among the many paralogisms urged on both sides in this controversy. If there be any difficulty in conceiving how dephlogisticated sulphur, or pure vitriolic acid, may displace phlogisticated vitriolic acid, or sulphur, the same will apply to the opposite theory, which asserts that aerated sulphur, or vitriolic acid, displaces de-aerated vitriolic acid, or pure sulphur. T.

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If he had exposed his liver of sulphur to the air in closed vessels, he would have seen that the vital air is absorbed, that the sulphure is decomposed, and that the sulphate of pot-ash, or vitriolated tartar is formed; which proves the recomposition of the sulphuric acid.

If charcoal be moistened with sulphuric acid or oil of vitriol, and then exposed to distillation, the products are carbonic acid or fixed air, sulphur, and much sulphureous or volatile vitriolic acid.

The experiments of Stahl exhibit the most perfect demonstration of the decomposition of the sulphuric acid into sulphur and oxigene; and it is not necessary, in the explanation of them, either to suppose the existence of an imaginary being, or to suppose that sulphur is a compounded body.

C H A P. III.

Concerning Carbone.

PURE charcoal is called Carbone in the new Nomenclature. This substance is placed among simple bodies, because no experiment has hitherto shewn the possibility of decomposing it.

Carbone

Carbone exists ready formed in vegetables. It may be cleared of all the volatile and oily principles by distillation; and, by subsequent washing in pure water, it may be deprived of all the salts which are mixed and confounded with it.

When it is required to procure carbone in a state of great purity, it must be dried by strong ignition in a closed vessel: this precaution is necessary; for the last portions of water adhere with such avidity, that they are decomposed, and afford hydrogenous gas and carbonic acid.

Carbone exists likewise in the animal kingdom: it may be extracted by a process similar to that which we have described; but its quantity is small. It appears in the form of a light spongy mass, difficultly consumed in the air, and mixed with a great quantity of phosphates, and even of fodar.

Carbone is likewise found in plumbago, of which it is one of the principles.

We shall treat more fully of this substance in the analysis of vegetables. But these concise ideas are sufficient to enable us to proceed in our account of its combinations, which is indeed the only object of the present short enumeration of its properties.

SECTION V.

Concerning Gases, or the Solution of certain Principles in Caloric, at the Temperature of the Atmosphere.

CALORIC, in its combination with bodies, volatilizes some of them, and reduces them to the æriform state. The permanence in this state in the temperature of the atmosphere constitutes the gases; so that, to reduce a substance to the state of gas, consists in dissolving it in caloric.

Caloric combines with various bodies, with greater or less facility; and we are acquainted with several that, at the temperature of the atmosphere, are constantly in the state of gas: there are others which pass to this state at some degrees higher, and these are called Volatile or Evaporable substances. They differ from fixed substances, because these last are not volatilized but by the application and combination of a strong dose of caloric.

It appears that all bodies do not indiscriminately require the same quantity of caloric to assume the gaseous state; and we shall see that

this proportion may be deduced from the fixation and concretion of these gaseous substances.

To reduce any substance to the state of gas, the application of caloric may be made in various manners.

The most simple method consists in placing the body in contact with another body which is heated. In this situation, the heat on one hand diminishes the affinity of aggregation or composition, by separating the constituent principles to a greater distance from each other; on the other hand, the heat unites to the principles with which it has the strongest affinity, and volatilizes them. This process is according to the method of simple affinities; for it in fact consists of the exhibition of a third body, which, presented to a compound of several principles, combines with one of them, and carries it off.

The method of double affinity may likewise be used to convert any substance into the gaseous form; and this is what happens when we cause one body to act upon another to produce a combination, in which a disengagement of some gaseous principles takes place. If I pour, for example, the sulphuric acid upon the oxide of manganese, the acid combines with the metal; while its caloric seizes the oxygen, and rises

rises with it. This principle takes place not only in this instance, but on all other occasions wherein, an operation being performed without the application of heat, there is a production of vapour or gas.

The various states under which bodies present themselves to our eyes, depend almost entirely upon the different degrees of combination of caloric with those same bodies. Fluids do not differ from solids, but because they constantly possess, at the temperature of the atmosphere, the dose of caloric which is requisite to maintain them in that state; they congeal and pass to the concrete state with greater or less facility, according as the requisite quantity of caloric is more or less considerable.

- All solid bodies are capable of passing to the gaseous state; and the only difference which exists between them in this respect is, that a dose of caloric is required for this purpose, which is governed—1. By the affinity of aggregation, which connects their principles, retains them, and opposes itself to a new combination. 2. By the weight of the constituent parts, which renders their volatilization more or less difficult. 3. By the agreement and attraction between the caloric and the solid body, which is more or less strong.

All bodies, whether solid or liquid, when they come to be volatilized by heat, appear in two states—that of vapour, or that of gas.

In the first case, these substances lose, in a short time, the caloric which raised them, and again appear in their original form the moment the caloric finds colder bodies to combine with; but it is rare that bodies thus divided resume their original consistence. The first state is that of vapour.

In the second case, the combination of caloric with the volatilized substance is such, that the ordinary temperature of the atmosphere is insufficient to overcome this union. This state constitutes the gases.

When the combination of caloric with any substance is such that a gas is produced, these invisible substances may be managed at pleasure, by the assistance of apparatus appropriated within our time to these uses. These apparatus are known by the name of Pneumato-chemical, Hydro-pneumatic apparatus, &c.

The pneumato-chemical apparatus, in general, consists of a wooden vessel, usually of a square form, and lined with lead or tin: two or three inches beneath the upper edge there is formed a groove, in which a wooden plank slides, having a hole in the middle, and a notch
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in one of its sides ; the hole is made in the centre of an excavation made in the shelf, of the figure of a funnel.

This vessel is filled with water or mercury, according to the nature of the gases operated upon. There are some which easily combine with water, and therefore require to be received over mercury.

The gases may be extracted in various manners.

When they are disengaged by fire, a recurved tube is adapted to the neck of the retort, one extremity of which is plunged in the water or the mercury of the pneumatological vessel, and opens beneath the aperture in the shelf, which is in the form of a funnel. The junction of the tube with the neck of the retort is secured with the usual lute ; a vessel filled with the liquid of the cistern is inverted upon the shelf over the aperture. When the gas is disengaged from the materials in the retort, it appears in the form of bubbles, which rise, and gain the superior part of the inverted vessel. When all the water is displaced, and the bottle is full of gas, it is withdrawn, by adapting a glass plate to its orifice to prevent its dissipation: it may then be poured from one vessel to another,

another, and subjected to a variety of experiments to ascertain its nature.

When the gases are disengaged by means of acids, the mixture which is designed to afford them is put into a bottle with a recurved tube fitted to its neck; and this tube is plunged in the cistern in such a manner, that the bubbles of gas may pass, as in the former experiment, through the aperture of the funnel in the shelf.

The processes at present used to extract the gases, and to analyse them, are simple and commodious: and these processes have singularly contributed to our acquisition of the knowledge of these æriform substances, whose discovery has produced a revolution in chemistry.

CHAP. I.

Concerning Hydrogenous Gas, or inflammable Air.

INFLAMMABLE Air is one of the constituent parts of water; a circumstance which has entitled it to the denomination of Hydrogenous Gas. Its property of burning with vital air has caused it to be distinguished by the name of Inflammable Air.

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Hydrogenous gas has been procured long since. The famous philosophical candle attests the antiquity of this discovery; and the celebrated Hales obtained from most vegetables an air which took fire.

Hydrogenous gas may be extracted from all bodies in which it is a constituent part; but the purest is that afforded by the decomposition of water, and it is this fluid which usually affords it in our laboratories. For this purpose the sulphuric acid is poured upon iron, or zinc; the water which serves as a vehicle for the acid, is decomposed on the metal; its oxygen combines with it, while the hydrogenous gas escapes. This explanation, however contrary to the ancient notion, is not the less a demonstrated truth; in fact, the metal exists in the state of an oxide in its solution by the sulphuric acid, as may be proved by precipitating it with pure vegetable alkali; on the other hand, the acid itself is not at all decomposed; so that the oxygenous gas cannot have been afforded to the iron but by the water. Water may be decomposed likewise still more directly by throwing it upon iron strongly heated; and hydrogenous gas may be obtained by causing water to pass through a tube of iron ignited to whiteness.

The hydrogenous gas may be extracted by
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the simple distillation of vegetables. Vegetable fermentation, and animal putrefaction, likewise produce this gaseous substance.

The properties of this gas are as follow :

A. Hydrogenous gas has a disagreeable stinking odour. Mr. Kirwan has observed, that when it is extracted over mercury, it has scarcely any smell. It contains half its weight of water, and loses its smell the moment it is deprived of this additional substance.

Kirwan has likewise observed, that the volume of hydrogenous gas is one-eighth larger when received over water than when received over mercury.

These observations appear to prove, that the offensive smell of this gas arises only from the water it holds in solution.

B. Hydrogenous gas is not proper for respiration. The abbé Fontana assures us that he could not take more than three inspirations of this air : the count Morrozo has proved that animals perish in it in a quarter of a minute. On the other hand, several northern chemists have affirmed, in consequence of experiments made on themselves, that hydrogenous gas might be respired without danger ; and it is some years since the unfortunate Pilatre du Rozier filled his lungs with it at Paris, and set it on fire

fire during the expiration, which forms a very curious jet of flame. It was remarked to him, that the abbé Fontana had objected against the accuracy of the Swedish chemists. This intrepid philosopher answered the objection, by mixing one-ninth of atmospherical air with very pure hydrogenous gas. He respired this mixture, as usual; but when he attempted to set it on fire, the consequence was an explosion so dreadful, that he imagined all his teeth were blown out.

This opposition of opinions and contradiction of experiments, respecting a phenomenon which seems capable of unanswerable decision by one single experiment, induced me to have recourse to trial, to fix my own ideas on the subject.

Birds, successively placed in a vessel of hydrogenous gas, died, without producing the smallest perceptible change in the gas itself.

Frogs placed in forty inches of hydrogenous gas died in the space of three hours and a half: while others lived fifty-five hours in oxygenous gas and atmospherical air; and when I took them out still living, the air was neither vitiated nor diminished. Numerous experiments which I have made upon these animals, have led me to observe that they have the faculty

culty of stopping their respiration, when placed in any noxious gas, to such a degree, that they inspire only once or twice, and afterwards suspend every function on the part of the respiratory organ.

I have since had occasion to observe that these animals are not reduced into a putrid mass by remaining in hydrogenous gas, as was affirmed some time ago. The fact which may have imposed on chemists who related this circumstance, is, that frogs are often enveloped in a mucus or sanies, which appears to cover them; but they exhibit the same phenomenon in all the gases.

After having tried the hydrogenous gas upon animals, I determined to respire it myself; and I found that the same volume of this air might be several times respired without danger. But I observed that this gas was not changed by these operations; whence I concluded that it is not respirable: for, if it were, it would suffer a change in the lungs, the object of respiration not being confined to the reception and emission of a fluid merely; it is a function much more noble, more interesting, more intimately connected with the animal œconomy: and we ought to consider the lungs as an organ which is nourished by the air, digests that which is presented

sented to it, retains the beneficial, and rejects the noxious part. Since therefore inflammable air can be respired several successive times without danger to the individual, and without any alteration or change in itself, we may conclude indeed that inflammable air is not a poison, but that it cannot be considered as an air essentially proper to respiration. It is with hydrogenous gas in the lungs, as with those balls of moss and resin which certain animals swallow during the rigorous season of the winter. These balls are not digested, since the animals void them at the return of spring: but they delude hunger; and the membranes of the stomach are exercised upon them without danger, in the same manner as the lungs exert themselves upon the hydrogenous gas presented to them.

C. Hydrogenous gas is not combustible alone; it does not burn but by the concurrence of oxigene. If a vessel filled with this gas be reversed, and a lighted taper be presented to it, the hydrogenous gas is found to burn at the surface of the vessel; but the candle is extinguished the moment it is plunged lower. The most inflammable bodies, such as phosphorus, do not burn in an atmosphere of hydrogenous gas.

D. Hydrogenous gas is lighter than common air.

air. One cubic foot of atmospheric air weighs seven hundred and twenty grains ; a cubic foot of hydrogenous gas weighs seventy-two grains. The barometer being at 29' 9, and the thermometer 60° Fahrenheit, Mr. Kirwan found the weight of this air to that of common air as eighty-four to one thousand ; consequently it was about twelve times as light.

Its specific gravity varies very much, because it is difficult to obtain it constantly of the same degree of purity. That which is extracted from vegetables contains the carbonic acid and oil, which increases its weight.

This levity of hydrogenous gas has caused certain philosophers to presume that it ought to arrive at and occupy the superior part of our atmosphere ; and upon this supposition the most brilliant conjectures have been made respecting the influence which a stratum of this gas, predominating over the rest of the atmosphere, ought to produce in meteorology. They were not aware that this continual loss of matter is not agreeable to the wise œconomy of nature. They did not observe that this gas, during its ascent in the air, combines with other bodies, more especially the oxigene, and that water and other products are the result ; the knowledge of which
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must necessarily lead us to that of most meteors.

The theory of balloons, or aërostatic machines, is founded on this levity of the hydrogenous gas.

In order that a balloon may rise in the atmosphere, it is sufficient that the weight of the balloon itself, and the air it encloses, should be less considerable than that of an equal bulk of atmospheric air ; and it must rise till its weight is in equilibrio with an equal volume of the surrounding air.

The theory of the Mongolfiers is every different from this. In this case a given volume of atmospheric air is rarefied by heat, and kept separated from the common mass by a hollow vessel of cloth. This rarefied space may therefore be considered for a moment as consisting of a mass of air of greater levity, which must necessarily make an effort to rise in the atmosphere, and carry its covering along with it.

E. Hydrogenous gas exhibits various characters according to its degree of purity, and the nature of the substances which are mixed with it.

It seldom happens that this gas is pure. That which is afforded by vegetables contains oil, and the carbonic acid. The inflammable air
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of marshes is mixed with a greater or less quantity of carbonic acid; and that which is afforded by the decomposition of pyrites sometimes holds sulphur in solution.

The colour of hydrogen, when set on fire, varies according to its mixtures. One-third of the air of the lungs, mixed with the inflammable air of pit-coal, affords a flame of a blue colour; inflammable air, mixed with nitrous air, affords a green colour; the vapour of ether affords a white flame. The various mixtures of these gases, and the degree of compression to which they are subjected, when expressed out of an aperture in order to burn them, have, in the hands of certain operators, afforded very agreeable illuminations, well deserving the attention of learned and curious observers.

F. Hydrogenous gas possesses the property of dissolving sulphur. In this case it contracts a stinking smell, and forms hepatic gas.

Mr. Gengembre put sulphur into inverted vessels filled with hydrogenous gas, and dissolved it by means of the burning-glass. The hydrogenous gas, by this treatment, obtained all the characteristic properties of hepatic gas. The formation of this gas is almost always an effect of the decomposition of water. In fact, the alkaline sulphures, or livers of sulphur, do
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not emit any disagreeable smell while they are dry; but the moment they are moistened, an abominable smell is perceived; and the sulphate of pot-ash, or vitriolated tartar, begins to be formed. These phenomena prove that the water is decomposed; that one of its principles unites to the sulphur, and volatilizes it; while the other combines with the alkali, and forms a more fixed product.

Sulphurated hydrogenous gas may be obtained by dissolving the sulphures or hepars by acids. Those acids in which the oxigene is most adherent disengage the greatest quantity. The muriatic acid produces twice as much as the sulphuric. That which is produced by this last, burns with a blue flame; but that which is disengaged by the muriatic acid, burns with a yellowish white flame.

Scheele has taught us the means of obtaining this gas in great abundance, by decomposing artificial pyrites, formed by three parts of iron and one of sulphur; to which spirit of vitriol is added.

The natural decomposition of pyrites in the bowels of the earth produces this gas; which escapes with certain waters, and communicates peculiar virtues to them.

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The most general properties of these gases are:

1. They render the white metals black,
2. They are improper for respiration.
3. They impart a green colour to syrup of violets.
4. They burn with a light blue flame, and deposit sulphur by this combustion.
5. They mix with the oxygenous gas of the atmospheric air, and form water; at the same time that the sulphur, before held in solution, falls down. Hence it happens that sulphur is found in the channels of hepatic waters, though their analysis does not shew the existence of an atom of that substance held in solution.
6. They impregnate water, and are sparingly soluble in that fluid; but heat or agitation dissipates them again.

The air which burns at the surface of certain springs, and forms what is known by the name of burning springs, consists of hydrogenous gas holding phosphorus in solution. It smells like putrid fish. The Pere Lampi has discovered one of these springs in the isles of St. Colom-bat. Dauphiny exhibits another similar spring at the distance of four leagues from Grenoble. The ignes fatui which glide along burying-grounds,

grounds, and which the superstitious people suppose to consist of the spirits of the departed, are phenomena of this nature, which we shall speak of when we come to treat of phosphorus.

CHAP. II.

Concerning Oxigenous Gas, or Vital Air.

THIS gaseous substance was discovered by the celebrated Priestley, on the 1st of August 1774. Since that memorable day, means have been devised of obtaining it from various substances; and its properties have shewn that it is a production of the most interesting nature in the knowledge of chemistry. No part of the atmosphere exhibits vital air in its greatest degree of purity. It is always combined, mixed, or altered by other substances.

But this air, which is the most general agent in the operations of nature, exists in combination with various substances; and it is by their

decomposition that it may be extracted and procured.

A metal exposed to the air becomes changed; and these changes are produced only by the combination of the pure air with the metal itself. Simple distillation of some of these metals thus changed, or oxides, is sufficient to disengage this vital air; and it is then obtained in a very pure state, by receiving it in the hydro-pneumatic apparatus. One ounce of red precipitate affords about a pint.

All acids have vital air for their base: there are some which yield it easily. The distillation of nitre decomposes the nitric acid; and about twelve hundred cubic inches of oxygenous gas are obtained from a pound of this salt.

The nitric acid, when distilled from various substances, is decomposed, and its constituent parts may be obtained separately.

Messrs. Priestley, Ingenhoufz, and Sennebier discovered nearly at the same time that vegetables exposed to the light of the sun emit vital air. We shall elsewhere speak of the circumstances of these phenomena; but shall at present confine ourselves to the observation, that the emission of vital air is proportioned to the vigour of the plant, and the vivacity of the light; and that the direct emission of the rays

of the sun is not necessary to produce this gaseous dew; it is sufficient that the plant be well enlightened, in order that it may transpire pure air: for I have often collected it in abundance from a kind of moss which covers the bottom of a vessel filled with water, and so well defended that the sun never shone directly upon it.

In order to procure the vital air which is disengaged from plants, it is sufficient to enclose them beneath a glass vessel filled with water, and inverted over a tub filled with the same fluid. The moment the plant is acted on by the sun, small bubbles of air are formed on its leaves, which detaching themselves rise to the upper part of the vessel, and displace the liquid.

This dew of vital air is a beneficial gift of nature, to repair incessantly the consumption of vital air. The plant absorbs atmospheric mephitic, and emits vital air. Man, on the contrary, is kept alive by vital air, and emits much mephitic. It appears therefore that the animal and vegetable kingdoms labour for each other; and that by this admirable reciprocity of services the atmosphere is continually repaired, and an equilibrium maintained between its constituent principles.

The influence of solar light is not confined to the production of vital air by its action upon

vegetables alone; it has likewise the singular property of decomposing certain substances, and disengaging this gas.

A bottle of oxygenated muriatic acid, exposed to the sun, suffers all the superabundant oxigene which it contained to escape, and passes to the state of ordinary muriatic acid. The same acid, exposed to the sun in a bottle wrapped in black paper, does not suffer any change; and, when heated in a dark place, is even reducible into gas without decomposition. The nitric acid likewise affords oxigenous gas, when exposed to the sun; whereas heat alone volatilizes it without decomposition.

The muriate, or marine salt of silver, placed under water, and exposed to the sun, suffers oxigenous gas to escape from it. I have observed that red precipitate likewise affords oxigene in similar cases, and that it becomes black in no very long space of time.

We may likewise obtain oxigenous gas by disengaging it from its bases by means of the sulphuric acid. The process to which I give the preference, on account of its simplicity, is the following:—I take a small apothecary's phial, into which I put one of two ounces of manganese, and pour thereon a sufficient quantity of sulphuric acid to form a liquid paste. I
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afterwards fit a cork to the opening of the bottle, with a hole through it, into which is inserted a recurved tube; one of whose extremities enters the bottle, while the other is placed under the saff of the pneumato-chemical apparatus. When the apparatus is thus disposed, I present a small coal to the lower part of the bottle, and oxygenous gas is immediately disengaged.

The manganese I use was discovered by me at St. Jean de Gardonnenque. It affords its oxygen with such facility, that nothing more is necessary for this purpose than to incorporate it with the sulphuric acid. This gas is not perceptibly mixed with nitrogenous gas (or phlogisticated air); and the first bubble is as pure as the last.

Oxygenous gas exhibits certain properties; according to its degree of purity. These depend in general upon the substances which afford it. That which is obtained from the mercurial oxides almost always holds a small quantity of mercury in solution: I have been a witness to its having produced a speedy salivation on two persons who used it for disorders of the lungs. In consequence of these observations, I filled bottles with this gas, exposed them to an intense cold, and the sides became obscured with a stratum

tum of mercurial oxide, in a state of extreme division. I have several times heated the bath, over which I caused this gas to pass; and I obtained, at two different times, a yellow precipitate in the bottle in which I had received the gas.

The oxygenous gas extracted from plants is not equally pure with that afforded by the metallic oxides: but from whatever substances it is obtained, its general properties are the following:

A. It is more ponderous than the air of the atmosphere; the cubic foot of atmospherical air weighing seven hundred and twenty grains, while the cubic foot of pure air weighs seven hundred and sixty-five. According to Mr. Kirwan, its weight is to that of common air as eleven hundred and three to one thousand. One hundred and sixteen inches of this air weighed 39,09 grains; one hundred and sixteen inches of common air weighed 35,38 grains at the temperature of ten degrees of Reaumur, and twenty-eight inches of pressure. One hundred parts of common air weighed forty six, and one hundred parts of vital air fifty.

B. Oxygenous gas is the only fluid proper for combustion. This acknowledged truth
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caused the celebrated Scheele to give it the name of Air of Fire.

To proceed with greater order in the examination of one of the most important properties of oxygenous gas, since it belongs exclusively to this fluid, we shall lay down the four following principles, as incontestable results of all the known facts.

The first principle.—Combustion never takes place without vital air.

The second principle.—In every combustion there is an absorption of vital air.

The third principle.—There is an augmentation of weight in the products of combustion equal to the weight of the vital air absorbed.

The fourth principle.—In all combustion there is a disengagement of heat and light.

I. The first of these propositions is a strict truth. Hydrogenous gas does not burn alone; without the assistance of oxygen; and all combustion ceases the moment that oxygenous gas is wanting.

II. The second principle contains a truth no less general. If certain bodies, such as phosphorus, sulphur, &c. be burned in very pure oxygenous gas, this is absorbed to the last particle; and when the combustion is effected in a mixture

mixture of several gases; the oxygen alone is absorbed, and the others remain unchanged. "

In the slower combustions, such as the rancidity of oils, and the oxidation of metals; there is equally an absorption of oxygen, as may be shewn by confining these bodies in a determinate mass of air.

III. The third principle, though not less true than the preceding, requires more explanation; and for this purpose we shall distinguish those combustions whose result, residue, and product are fixed, from those which afford volatile and fugacious substances. In the first case the oxygenous gas quietly combines with the body; and by weighing the same body the moment the combustion has completely taken place, it is easily ascertained whether the increase in weight be proportioned to the oxygen absorbed. This happens in all the cases wherein the metals are oxidized, or oils rendered rancid; and in the production of certain acids, such as the phosphoric, the sulphuric, &c. In the second case, it is more difficult to weigh all the results of the combustion, and consequently to ascertain whether the augmentation in weight be proportioned to the quantity of the air absorbed. Nevertheless, if the combustion be made in inverted vessels, and
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the whole of the products be collected, it is found that their augmentation in weight is strictly equal to that of the air absorbed.

IV. The fourth principle is that whose applications are the most interesting to be known.

In most combustions, the oxygenous gas becomes fixed and concrete. It therefore abandons the caloric which maintained it in the æiriform state ; and this caloric being set at liberty, produces heat, and endeavours to combine itself with the substances nearest at hand.

The disengagement of the heat is therefore a constant effect in all the cases wherein vital air is fixed in bodies ; and it follows, from this principle—1. That heat is most eminently resident in the oxygenous gas which maintains combustion. 2. That the more oxigene is absorbed in a given time, the stronger will be the heat. 3. That the only method of producing a violent heat consists in burning bodies in the purest air. 4. That fire and heat must be more intense in proportion as the air is more condensed. 5. That currents of air are necessary to maintain and expedite combustion. It is upon this principle that the theory of the effects of the cylinder lamps is founded : the current of air, which is renewed through the tube, supplies fresh air every instant ; and by continually applying

plying a new quantity of oxygenous gas to the flame, a heat is produced sufficient to ignite and destroy the smoke.

It is likewise on the same principle that we explain the great difference that exists between heat produced by a slow combustion, and that which is afforded by rapid combustion. In the latter case the same quantity of heat and light is produced in a second, which might have been produced in the other case in a much longer time.

The phenomena of combustion, by means of oxygenous gas, depend likewise upon the same laws. Professor Lichtenberger, of Gottingen, soldered the blade of a knife to a watch spring by means of oxygenous gas; Messrs. Lavoisier and Erhmann have subjected almost all the known bodies to the action of fire maintained by oxygenous gas alone; and they produced effects which the burning-glass could not have operated.

Mr. Ingenhoufz has shewn us, that if an iron wire be bent into a spiral form, and any combustible substance whatever be fixed to one of its ends, and set on fire, the wire will itself be fused by plunging it into oxygenous gas.

Mr. Forster, of Gottingen, found that the light of glow-worms is so beautiful and bright
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in oxigenous gas, that one single insect was sufficient to afford light to read the *Annales Savantes* of Gottingen, printed in a very small character. Nothing more is wanting therefore than to apply this air to combustion with facility and œconomy; and Mr. Meusnier has succeeded in this, by constructing a simple and commodious apparatus. On this subject the treatise of Mr. Erhmann upon fusion may be consulted.

The description of the gazometer may likewise be seen in the *Elementary Treatise of Chemistry*, by Mr. Lavoisier.

We shall distinguish three states in the very act of combustion—ignition, inflammation, and detonation.

Ignition takes place when the combustible body is not in the æriform state, nor susceptible of assuming that state by the simple heat of combustion. This happens when well-made charcoal is burned.

When the combustible body is presented to oxigenous gas, in the form of vapour or gas, the result is flame; and the flame is more considerable, in proportion as the combustible body is more volatile. The flame of a candle is not kept up but by the volatilization of the wax, which is continually effected by the heat of the combustion.

Deto-

Detonation is a speedy and rapid inflammation, which occasions a noise by the instantaneous formation of a vacuum. Most detonations are produced by the mixture of hydrogenous and oxygenous gas, as I have shewn in my Memoir upon Detonations; in the year 1781. It has been since proved, that the product of the rapid combustion of these two gases is water. Very strong detonations may be produced by burning a mixture of one part of oxygenous gas with two of hydrogenic. The effect may be rendered still more terrible, by causing the mixture to pass through soap-water, and setting fire to the bubbles which are heaped on the surface of the fluid.

Chemistry presents several cases in which the detonation arises from the sudden formation of some gaseous substances, such as that which is produced by the inflammation of gunpowder; for in this case there is a sudden production of carbonic acid, of nitrogene gas, &c. The production or instantaneous creation of any gas whatever, must occasion a shock or agitation in the atmosphere, which necessarily affords an explosion; the effect of these explosions increases, and becomes stronger, from the opposition of any obstacles against the escape of the gas.

C. Oxygenous gas is the only gas proper for
respira-

respiration. It is this most eminent property which has entitled it to the name of Vital Air, and we shall give the preference to this denomination in the present article.

It has long since been known that animals cannot live without the assistance of air. But the phenomena of respiration have been very imperfectly known until lately.

Of all the authors who have written concerning respiration, the ancients are those who have had the most accurate ideas of it. They admitted in the air a principle proper to nourish and support life, which they denoted by the name of *pneumum vite*; and Hippocrates expressly says, *spiritus etiam alimentum est*. This idea, which was connected with no hypothesis, has been successively replaced by systems void of all foundation. Sometimes the air has been considered as a stimulus in the lungs, which kept up the circulation by its continual action. Vide Haller.—Sometimes the lungs have been considered as bellows designed to cool the body, heated by a thousand imaginary causes: and when it was proved that the volume of air was diminished in the lungs, it was thought to be an explanation of every difficulty, to say that the air was deprived of its spring.

At this day, however, we are enabled to throw
some

some light on one of the most important functions of the human body. In order to proceed with more perspicuity, we shall reduce our notions to several principles.

1. No animal can live without the assistance of air. This fact is universally admitted; but it has not been known until lately that the faculty which the air possesses of answering the purpose of respiration, arises only from one of the principles of atmospheric air, known by the name of vital air.

2. All animals do not require the same purity in the air. Birds, as well as men, and the greatest part of quadrupeds, require a very pure air; but those which live in the earth, or which hide themselves in a state of stupefaction during the winter, can subsist by means of a less pure air.

3. The manner of respiring the air is different in the several subjects. In general, nature has given to animals an organ, which by its involuntary dilatation and contraction receives and expels the fluid in which the animal moves and exists. This organ is more or less perfect, more or less concealed and defended from external injury, according to its importance, and influence upon the life of the creature, as Mr. Broussonnet has observed.

Amphi-

Amphibious animals respire by means of lungs: but they can suspend their motion even whilst they are in the air; as I have observed with regard to frogs, which stop their respiration at pleasure.

The manner of respiration in fishes is very different; these animals come from time to time to inhale the air at the surface of the water; where they fill their vesicle, and digest it afterwards at their ease. I have for a long time observed the phenomena of fishes in the act of respiration; and am well assured that they are sensible of the action of all the gases, like other animals. Mr. De-Fourcroy has observed that the air contained in the vesicle of the carp is nitrogene gas (phlogificated air).

Insects with tracheæ exhibit organs still more remote from ours in their construction. In these animals; respiration is effected by the tracheæ distributed along the body. They accompany all the vessels, and terminate by losing themselves in insensible pores at the surface of the skin.

These insects appear to me to exhibit several very evident points of analogy with vegetables.

1. Their respiratory organs are formed in the same manner, being disposed through the whole body of the vegetable and the animal.—

2. In-

2. Insects do not require a great degree of purity in the air; and plants are nourished with atmospherical mephitic.—3. Both the one and the other transpire vital air. The abbé Fontana discovered several insects in stagnant waters, which, when exposed to the sun, afforded vital air: and the green matter which is formed in stagnant waters, and is by Dr. Priestley placed among the *conservæ*, in conformity with the opinion of his friend Mr. Bewley—which Mr. Senebier has supposed to be the *conserva cespitosa filis rectis undique divergentibus Halleri*, and which has appeared to Dr. Ingenhousz to be nothing else but a mass of animalcula—affords a prodigious quantity of this air when exposed to the sun.—4. Insects likewise afford, by chemical analysis, principles similar to those of plants, such as resins, volatile oils, &c.

Father Vaniere appears to have known, and very elegantly expressed, the property of vegetables to support themselves by means of vital air:

. . . Arbor enim (res non ignota), ferarum
 Infat et halituum, piscisque latentis in imo
 Gurgite, vitales et reddit et accipit auras.

PROVERBIIUM RUSTICUM, l. vi.

Animals with lungs respire only by virtue of the vital air which surrounds them. Any gas deprived

deprived of this mixture becomes immediately improper for respiration: and this function is exercised with so much the greater liberty, as vital air exists in a greater proportion in the air respired.

Count Morozzo placed successively several full-grown sparrows under a glass bell, inverted over water. It was at first filled with atmospheric air, and afterwards with vital air. He observed—

1. In atmospheric air,	Hours.	Min.
The first sparrow lived	3	0
The second -	0	3
The third -	0	1

The water rose in the vessel eight lines during the life of the first; four during the life of the second; and the third produced no absorption.

2. In vital air,	Hours.	Min.
The first sparrow lived	5	23
The second -	2	10
The third -	1	30
The fourth -	1	10
The fifth -	0	30
The sixth -	0	47
The seventh -	0	27
The eighth -	0	39
The ninth -	0	22
The tenth -	0	21

From these experiments it may be concluded,
 1. That an animal lives longer in vital air than in atmospherical air. 2. That an animal can live in air in which another has died. 3. That, independent of the nature of the air, respect must be had to the constitution of the animals, as the sixth lived forty-seven minutes, and the fifth only thirty. 4. That there is either an absorption of air, or the production of a new kind of air, which is absorbed by the water as it rises.

It remains, at present, to examine what are the changes produced by respiration. 1. In the air. 2. In the blood.

The gas emitted by expiration is a mixture of nitrogene gas, carbonic acid, and vital air. If the air which issues from the lungs be made to pass through lime-water, it renders it turbid; if it be received through tincture of turnsole, it reddens it; and if a pure alkali be substituted instead of the tincture of turnsole, it becomes effervescent.

When the carbonic acid has been absorbed by the foregoing process, the remainder of this air consists of nitrogene gas and vital air. The vital air is shewn to be present by means of nitrous air. The air in which I had caused five sparrows to perish, afforded seventeen hundredth parts of vital air. After having thus deprived the

the expired air of all its vital air, and all its carbonic acid, the remainder is nitrogene gas.

It has been observed that frugivorous animals vitiate the air less than carnivorous animals.

A portion of the air is absorbed in respiration. Borelli formerly took notice of this; and Dr. Jurin had calculated that a man inspired forty cubic inches of air in his usual inhalations, and that in the greatest he could receive two hundred and twenty inches; but that a portion was always absorbed. The celebrated Dr. Hales endeavoured to determine this absorption more strictly, and he estimated it at a sixty-eighth of the total of the respired air; but he did not consider it as more than a hundred and thirty-sixth, on account of errors which he supposed to have taken place. Now a man respire twenty times in a minute, and inhales forty cubic inches of air at each inspiration; this makes forty-eight thousand per hour; which, divided by one hundred and thirty-six, gives about three hundred and fifty-three inches of air absorbed and destroyed in the hour. The process of Hales is not exact; because he passed the air expired through water, which must have retained a sensible proportion.

From more accurate experiments, Mr. De la

Metheric has proved, that three hundred and sixty cubic inches of vital air are absorbed in an hour.

My experiments have not shewn near so great a loss,

This fact affords a proof of the facility with which air is vitiated by respiration when it is not renewed, and shews why the air of theatres is in general so unwholesome.

II. The first effect which the air appears to produce upon the blood is, that of giving it a vermilion-colour. If the blackish venous blood be exposed in a pure atmosphere, it becomes of a vermilion-colour at its surface: this fact is daily observed when blood is suffered to remain exposed in a porringer to the air. Air which has remained in contact with blood, extinguishes candles, and precipitates lime-water. Air injected into a determinate portion of a vein between two ligatures, renders the blood of a higher colour, according to the fine experiments of Dr. Hewson.

The blood which returns from the lungs is of a higher colour, according to the observations of Messrs. Cigna, Hewson, &c. Hence arises the great intensity of the colour of arterial blood, compared with venous blood.

Mr. Thouvenel has proved, that by withdrawing

drawing the air which is in contact with the blood, it may be again made to lose its colour.

Mr. Beccaria exposed blood in a vacuum, where it remained black, but assumed the most beautiful vermilion-colour as soon as it was again exposed to the air. Mr. Cigna covered blood with oil, and it preserved its black colour.

Dr. Priestley caused the blood of a sheep to pass successively into vital air, common air, mephitic air, &c. and he found that the blackest parts assumed a red colour in respirable air, and that the intensity of this colour was in proportion to the quantity of vital air present. The same philosopher filled a bladder with blood, and exposed it to pure air. That portion of blood which touched the surface of the bladder, became red, while the internal part remained black; an absorption of air therefore took place through the bladder, in the same manner as when the contact is immediate.

All these facts incontestably prove, that the vermilion-colour assumed by the blood in the lungs, is owing to the pure air which combines with it.

The vermilion colour of blood is therefore the first effect of the contact, absorption, and combination of pure air with the blood.

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The second effect of respiration is to establish a real focus of heat in the lungs; which is a circumstance very opposite to the precarious and ridiculous notion of those who have considered the lungs as a kind of bellows designed to cool the human body.

Two celebrated physicians, Hales and Boerhaave, have observed that the blood acquired heat in passing through the lungs; and modern physiologists have estimated this augmentation of heat at eleven hundredths.

The heat in each class of individual animals is proportioned to the magnitude of their lungs, according to Messrs. De Buffon and Broussonnet.

Animals with cold blood have only one auricle and one ventricle, as Aristotle observed.

Persons who have respired vital air, agree in affirming that they perceived a gentle heat vivifying the lungs, and insensibly extending from the breast into all other parts of the body.

Ancient and modern facts unite therefore to prove, that a focus of heat really exists in the lungs, and that it is maintained and kept up by the air of respiration. We are able, at present, to explain all these phenomena. In fact, there is an absorption of vital air in respiration. Respiration then may be considered as an operation

tion by means of which vital air passes continually from the gaseous to the concrete state ; it must therefore at each instant abandon the heat which held it in solution, and in the state of gas. This heat produced at every inspiration must be proportioned to the volume of the lungs, to the activity of this organ, to the purity of the air, the rapidity of the inspirations, &c. Hence it follows that during the winter, the heat produced must be more considerable, because the air is more condensed, and exhibits more vital air under the same volume. By the same reason, respiration ought to produce more heat in the inhabitants of northern climates ; and this is one of the causes prepared by nature to temperate, and continually balance, the extreme cold of these climates. It follows likewise that the lungs of asthmatic persons are less capable of digesting the air ; and I am assured that they emit the air without vitiating it ; from which cause their complexion is cold, and their lungs continually languishing ; vital air is therefore wonderfully comfortable to them. It may be easily conceived from these principles why the heat of animals is proportioned to the volume of their lungs ; and why those which have only one auricle, and one ventricle, have cold blood, &c.

The phenomena of respiration are therefore the same as those of combustion.

Vital air, by combining with the blood, forms the carbonic acid, which may be considered as antiputrescent as long as it remains in the circulation; and that it is afterwards emitted through the pores of the skin, according to the experiments of the count De Milly, and the observations of Mr. Fouquet.

Vital air has been used with success in certain disorders of the human body. The observations of Mr. Caillens are well known. He caused persons affected with phthical disorders to respire it with the greatest success. I have myself been a witness to the most wonderful effects of this air in a similar case. Mr. De B—— was in the last stage of a confirmed phthisis. Extreme weakness, profuse sweats, a flux of the belly, and in short every symptom, announced the approach of death. One of my friends, Mr. De P——, put him upon a course of vital air. The patient respired it with delight, and asked for it with all the eagerness of an infant at the breast. During the time that he respired it he felt a comfortable heat, which distributed itself through all his limbs. His strength increased with the greatest rapidity; and in six weeks he was able to take long walks.

This

This state of health lasted for six months: but after this interval he relapsed; and being no longer able to have recourse to the use of vital air, because Mr. De P—— had departed for Paris, he died.—I am very far from being of opinion that the respiration of vital air ought to be considered as a specific, in cases of this nature. I am even in doubt whether this powerful air is perfectly adapted to such circumstances; but it inspires cheerfulness, renders the patient happy, and in desperate cases it is most certainly a precious remedy, which can spread flowers on the borders of the tomb, and prepare us in the gentlest manner for the last dreadful effort of nature.

The absolute necessity of vital air in respiration, enables us to lay down positive principles for purifying the corrupted air of any given place. This may be done in three ways. The first consists in correcting the vitiated air by means of substances which are capable of seizing the noxious principles. The second consists in displacing the corrupted air, and substituting fresh air in the room of it; as is done by means of ventilators, the agitation of doors, &c. And the third consists in pouring into the mephitised atmosphere a new quantity of vital air.

The

The processes employed in purifying corrupted air, are not all certain in their effects. The fires which are lighted for this purpose have no other advantage than to establish ascending currents, and to burn unhealthy exhalations; and perfumes do nothing more than disguise the bad smell, without changing the nature of the air, as the experiments of Mr. Achard shew.

C H A P. III.

Concerning Nitrogene Gas, Azote, or Atmospheric Mephitic.

IT has been long since ascertained, that air which has served the purposes of combustion and respiration, is no longer proper for those uses; the air thus corrupted has been distinguished by the names of Phlogisticated Air, Mephitised Air, Atmospheric Mephitic, &c. I call it Nitrogene Gas, for the reasons explained in the Preliminary Discourse.

But this residue of combustion or respiration is always mixed with a small quantity of vital air and carbonic acid, which must be removed in order to have the nitrogene gas in a state of purity. There are several methods which
may

may be used to obtain nitrogene gas, in a very pure state.

1. Scheele has taught us, that by exposing sulphure of alkali, or liver of sulphur, in a vessel filled with atmospherical air, the vital air is absorbed; and, when the absorption is complete, the nitrogene gas remains pure.

By exposing, in atmospheric air over mercury, a mixture of iron and sulphur, kneaded together with water, Mr. Kirwan obtained nitrogene gas so pure, that it suffered no diminution by nitrous gas. He deprived it of all humidity, by successively introducing dried blotting-paper into the vessel which contained it. Care must be taken to withdraw this air in time from the paste which affords it; otherwise it will be mixed with hydrogen or inflammable gas, which is afterwards disengaged. 2. When by any means, such as the oxidation of metals, the rancidity of oils, the combustion of phosphorus, &c. the vital air of the atmosphere is absorbed, the residue is nitrogene gas. All these processes afford methods of greater or less accuracy to determine the proportions of vital air and nitrogene gas in the composition of the atmosphere.

3. This mephitic may likewise be procured by treating muscular flesh, or the well-washed fibrous part of blood, with nitric acid in the hydro-

hydro-pneumatic apparatus. But it must be carefully observed that these animal matters ought to be fresh; for, if they have begun to be changed by the putrid fermentation, they afford carbonic acid mixed with hydrogen gas.

A. This gas is improper for respiration and combustion.

B. Plants live in this air, and freely vegetate in it.

C. This gas mixes with the other airs, without combining with them.

D. It is lighter than the atmospheric air, the barometer standing at 30.46, and Fahrenheit's thermometer at 60: the weight of nitrogen gas is to that of common air as nine hundred and eighty-five to one thousand.

E. Mixed with vital air, in the proportion of 72 to 28, it constitutes our atmosphere. The other principles which analysis exhibits in the atmosphere, are only accidental, and by no means necessary.

SECTION VI.

**Concerning the Mixture of Nitrogene and
Oxigene Gas; or of Atmospheric Air.**

THE gaseous substances we have treated of seldom exist alone and insulated; nature presents them every where to our observation in a state of mixture or of combination. In the first case these gases preserve the æri-form state; in the second they for the most part form fixed and solid bodies. Nature, in its several decompositions, reduces almost all the principles of bodies into gas. These new substances unite together, combine, and from thence result compounds of considerable simplicity in their principles, but which become complicated by subsequent mixture and combinations. We may follow the operations of nature, step by step, without departing from the plan we have adopted.

The mixture of about seventy-two parts of nitrogene gas, and twenty-eight of oxigene, forms this fluid mass in which we live. These two principles are so well mixed, and each of them is so necessary to the support of the various functions of individuals which live or
vegetate

vegetate upon the globe, that they have not yet been found separate and alone.

The proportion of these two gases is subject to variation in the mixture which forms the atmosphere: but this difference depends only upon local causes: and the most usual proportion is that which we have here mentioned.

The characteristic properties of vital air are modified by those of nitrogene gas, and these modifications even seem to be necessary; for if we were to respire vital air in its state of purity, it would quickly consume our life; and this virgin air is no more suitable to our existence than distilled water. Nature does not appear to have designed us for the use of these principles in their greatest degree of perfection.

The atmospheric air is elevated several leagues above our heads, and fills the deepest subterraneous cavities. It is invisible, insipid, inodorous, ponderous, elastic, &c. It was the only gaseous substance known before the present epocha of chemistry; and the infinite gradations of all the invisible fluids which presented themselves so frequently to the observation of philosophers, were always attributed to modifications of the air. Almost the whole of what has been written upon the air relates only
to

to its physical properties. We shall confine ourselves to point out the chief of these.

A. Air is a fluid of extreme rarefaction, obedient to the smallest motion : the slightest percussion deranges it ; and its equilibrium, which is continually destroyed, is continually endeavouring to restore itself.

Though very fluid, it passes with difficulty through orifices by means of which grosser liquids can easily penetrate. This has caused philosophers to suppose that its parts were of a branched form*.

B. The atmospheric air is invisible. It refracts the rays of light without reflecting them : for it is without sufficient proofs that some philosophers have imagined that large masses of this fluid are of a blue colour.

It appears that the air is inodorous itself ; though it is the vehicle of odorant particles.

It may be considered as insipid ; and when its contact affects us variously, we ought to attribute it to its physical qualities.

C. It was not until the middle of the last

* This is a deception. It is true that the cohesive attraction renders it difficult to displace any dense fluid from a capillary tube by the intrusion of air ; but every experiment of the air-pump, the condenser, and the barometer, shews with what facility the air passes through the smallest orifices. T.

century that its weight was ascertained by accurate experiments. The impossibility of supporting water in a tube open at the bottom, to a greater height than thirty-two feet, caused Torricellius to suspect that an external cause supported the liquid at that height, and that it was not the horror of a vacuum which precipitated the water in the barrels of pumps. This celebrated philosopher filled a tube closed at one of its extremities with mercury : he reversed this into a vessel filled with the same metal ; and observed that the mercury, after several oscillations, constantly subsided to the height of twenty-eight inches. He immediately saw that the difference of elevations corresponded with the relative weights of these two fluids, which are in the proportion of fourteen to one. The immortal Pascal proved, some time afterwards, that liquids were supported at this elevation by a column of atmospherical air ; and ascertained that their height varies according to the length of the column which presses upon them.

D. The elasticity of the air is one of the properties upon which natural philosophers have made the greatest number of experiments ; and it has even been applied to considerable advantage in the arts.

S E C.

SECTION VII.

Concerning the Combination of Oxigenous Gas and Hydrogene, which forms Water.

WATER has been long considered as an elementary principle ; and when accurate experiments had compelled chemists to class it among compound substances, a resistance and opposition were made to it, which were not manifested when the air, the earth, and the other matters reputed to be elementary, were subjected to similar revolutions. It seems to me, however, that this analysis is equally strict with that of the air. Water is decomposed by several processes ; it is formed by the combination of oxigene and hydrogene : and we find that all the phenomena of nature and art conspire to prove the same truth. What more can be required to afford an absolute certainty respecting any physical fact ?

Water is contained in bodies in a greater or less quantity, and may be considered in two

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states: it is either in the state of simple mixture, or in a state of combination. In the first case, it renders bodies humid, is perceptible to the eye, and may be disengaged with the greatest facility. In the second, it exhibits no character which shews that it is in a state of mixture. It exists in this form in crystals, salts, plants, animals, &c. It is this water which the celebrated Bernard has called Generative Water; and of which he has made a fifth element, to distinguish it from exhalative water.

Water, existing in a state of combination in bodies, concurs in imparting to them hardness and transparency. Salts, and most stony crystals, lose their transparency when they are deprived of their water of crystallization.

Some bodies are indebted to water for their fixity. The acids, for example, acquire fixity only by combining with water.

Under these various points of view, water may be considered as the general cement of nature. The stones and salts which are deprived of it, become pulverulent; and water facilitates the coagulation, re-union, and consistence of the particles of stones, salts, &c. as we shall see in the operations performed with plasters, lutes, mortar, &c.

Water, when disengaged from its combinations,

tions, and in a state of absolute liberty, is one of the most considerable agents in the operations of this globe. It bears a part in the formation and decomposition of all the bodies of the mineral kingdom: it is necessary to vegetation, and to the free exercise of most of the functions of animal bodies; and it hastens and facilitates the destruction of these bodies, as soon as they are deprived of the principle of life.

For a certain time water was thought to be a fluid earth. The distillation, trituration, and putrefaction of water, which always left an earthy residue, afforded credit to an opinion that it was converted into earth. On this subject, the works of Wallerius and Margraff may be consulted: but Mr. Lavoisier has shewn that this earth arises from the wear of the vessels; and the celebrated Scheele has proved the identity of the nature of this earth with that of the glass vessels in which the operations were made. So that the opinions of the philosophical world are at present decided in this respect.

In order to obtain accurate ideas of a substance so necessary to be known, we will consider water under its three different states of solidity, fluidity, and gas.

ARTICLE I.**Concerning Water in the State of Ice.**

Ice is the natural state of water, whenever it is deprived of a portion of that caloric with which it is combined when it appears in the form of a liquid or gas.

The conversion into ice is attended with several phenomena which seldom vary.

A. The first of all, and at the same time the most extraordinary, is a sensible production of heat at the moment in which the water passes to the solid state. The experiments of Messrs. Fahrenheit, Treiwald, Baumé, De Ratte, leave no doubt on this subject; so that the water is colder at the instant of congelation than the ice itself.

A slight agitation of the fluid facilitates its conversion into ice, nearly in the same manner as the slightest motion very frequently determines the crystallization of certain salts. This arises, perhaps, from the circumstance, that by this means the caloric, which is interposed between the particles, and may oppose itself to the production of the phenomenon, may be expressed

expressed or disengaged. In proof of this opinion, it is seen that the thermometer rises at the very same instant, according to Fahrenheit.

B. Frozen water occupies a larger space than fluid water: we are indebted to the Academy del Cimento for the proofs of this truth. In their experiments, bomb shells, and the strongest vessels, being filled with water, were burst into pieces by the congelation of this fluid. The trunks of trees are divided and split with a loud noise, as soon as the sap freezes; and so likewise stones are broken in pieces the moment the water with which they are impregnated passes to the state of ice.

C. Ice appears to be nothing more than a confused crystallization. Mr. De Mairan observed that the needle-formed crystals of ice unite in an angle of either sixty or one hundred and twenty degrees.

Mr. Pelletier observed, in a piece of fistulous ice, crystals in the form of flattened triangular prisms, terminated by two dehdral summits.

Mr. Sage observes, that if a piece of ice, which contains water in its internal parts, be broken, the water runs out, and the internal cavity is found to be lined with beautiful tetrahedral prisms, terminated in four-sided prisms. These prisms are often articulated and crossed.

Vide

Vide M. Sage, *Annales de Chimie*, tom. i. p. 77.

Mr. Machart has observed, that when it snows at Moscow, and the atmosphere is not too dry, the air is observed to be loaded with beautiful crystallizations regularly flattened, and as thin as a leaf of paper. They consist of an union of fibres which shoot from the same centre to form six principal rays, and these rays divide themselves into small blades extremely brilliant: he observed several of these flattened radii which were ten lines in diameter.

D. When water passes from the solid to the liquid state, it produces cold by the absorption of a portion of heat, as is confirmed by the fine experiments of Wilcke. This production of cold, by the fusion of ice, is likewise proved by the practice of the confectioners, who fuse certain salts with ice, in order to produce a degree of cold below zero.

Ice is found in many places in great masses, known by the name of Glacieres; certain mountains are constantly covered with them, and the southern ocean abounds with them. The ice formed by salt water affords fresh water when melted; and in several northern provinces water is said to be concentrated by frost, to collect the salt it holds in solution. I have likewise observed,

observed, that several metallic salts are precipitated by exposing their solutions to a temperature sufficient to freeze them. The ice which was formed did not possess the characters of the salt which had been dissolved.

Hail and snow are nothing but modifications of ice. We may consider hail as produced by the sudden disengagement of the elastic fluid, which concurs in rendering water liquid: it is almost always accompanied with thunder. The experiments of Mr. Quinquet have confirmed this theory.—I will here relate a fact to which I myself was witness, at Montpellier, and of which philosophers may advantageously avail themselves. On the 29th of October, 1786, four inches of water fell at Montpellier; a violent explosion of thunder, which was heard about four in the evening, and which appeared to be very near, caused a most dreadful shower of hail. At this instant a druggist, who was employed in his cellar in preventing the mischief occasioned by the filtration of water through the wall, was highly astonished to behold that the water which came through the wall was instantly changed into ice. He called in several neighbours to partake of his surprise. I visited the place a quarter of an hour afterwards, and found ten pounds of ice at the foot of the wall; I was well

well assured that it could not have passed through the wall, which did not exhibit any crack, but appeared to be in very good condition. Did the same cause, which determined the formation of hail in the atmosphere, act equally in this cellar?—I relate the fact only, and forbear to make any conjecture upon it.

ARTICLE II.

Concerning Water in the Liquid State.

The natural state of water appears to be that of ice: but its most usual state is that of fluidity; and under this form it possesses certain general properties, which we shall proceed to describe.

The experiments of the Academy del Cimento have caused the philosophical world to deny the least elasticity to water, because it escaped through the pores of balls of metal strongly compressed, rather than yield to pressure. But Messrs. Zimmerman, and the abbé Mongez, have endeavoured to prove its elasticity from the very experiments upon which the contrary opinion has been built*.

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* The experiments of Canton, to prove the compressibility of water, are well known, and may be seen in the Philosophical

The liquid state renders the force of aggregation in water less powerful, and it enters into combination more readily in this form. Water which flows on the surface of our globe is never pure. Rain-water is seldom exempt from some mixture, as appears from the fine series of experiments of the celebrated Margraff. I have ascertained, at Montpelier, that the rain-water in storms is more impure than that of a gentle shower—that the water which falls first is less pure than that which falls after several hours or several days rain—that the water which falls when the wind blows from the sea to the southward, contains sea-salt; whereas that which is produced by a northerly wind, does not contain a particle.

Hippocrates has made several very important observations respecting the various qualities of water, relative to the nature of the soil, the temperature of the climate, &c.

As it is of importance to the chemist to have very pure water for several delicate operations,

phical Transactions. He enclosed water in spherical glass vessels, from which a narrow neck proceeded, like that of a thermometer: the water was found to occupy a larger space when the pressure of the atmosphere was removed by the air-pump, and a less space when a greater pressure was added by the condenser. T. 1789, vol. 1, p. 100.

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it is necessary to point out the means which may be used to carry any water whatever to this degree of purity.

Water is purified by distillation. This operation is performed in vessels called Alembics. The alembic is composed of two pieces; a boiler or cucurbit, and a covering called the capital or head,

The water is put into the cucurbit, from which it is raised in vapours by means of fire, and these vapours are condensed by cooling the head with cold water. The condensed vapours flow into a vessel designed to receive them. This is called Distilled Water; and is pure, because it has left behind it in the cucurbit the salts and other fixed principles which altered its purity.

Distillation is more speedy and quick, in proportion as the pressure of the air is less upon the surface of the stagnant fluid. Mr. Lavoisier distilled mercury *in vacuo*; and the abbé Rochon has made a happy application of these principles to distillation. It is to this same principle that we must refer the observations of almost all naturalists and philosophers, who have remarked, that the ebullition in the liquid becomes more easy, in proportion as we ascend a mountain from any other elevation; and it is
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in consequence of these principles, that Mr. Achard constructed an instrument to determine the heights of mountains, by the degrees of temperature of the ebullition of boiling water.

The abbé Mongez, and Mr. Lamanow, observed that ether evaporates with prodigious facility upon the peak of Teneriffe; and Mr. De Saussure has confirmed these experiments on the mountains of Switzerland.

A true distillation is carried on every where at the surface of our globe. The heat of the sun raises water in the form of vapours; these remain a certain time in the atmosphere, and afterwards fall in the form of dew, by simple refrigeration. This rise and fall of humidity, which succeed each other, wash and purge the atmosphere of all those particles, which by their corruption or development might render it infectious; and it is perhaps this combination of various miasmata with water which renders the evening dew so unwholesome.

It is to a similar natural distillation that we ought to refer the alternate transition of water from the liquid state to that of vapour, which forms clouds, and by this means conveys the water from the sea to the summits of mountains, from which it is precipitated in torrents, to return again to the common receptacle.

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We find traces of the distillation of water in the most remote ages. The first navigators in the islands of the Archipelago filled their pots with salt-water, and received the vapour in sponges placed over them. The process of distilling the water of the sea has been successively brought to perfection; and Mr. Poissonnier has exhibited a very well constructed apparatus to procure fresh water at all times in abundance.

Pure water requires to be agitated, and combined with the air of the atmosphere, to render it wholesome. Hence, no doubt, it is, that water immediately produced by melting snow, is unfit to drink.

The characters of potable water are the following:

1. A lively, fresh, and agreeable taste.
2. The property of boiling readily, and also that of boiling pease and other pulse.
3. The virtue of dissolving soap without curdling.

ARTICLE III.

Concerning Water in the State of Gas.

Many substances are naturally in the state of an æriform fluid, at the degree of the temperature

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ture of our atmosphere : such, for example, are the carbonic acid ; and the oxygenous, the hydrogenous, and the nitrogenous gases.

Other substances evaporate at a degree of heat very near that in which we live. Ether and alcohol are in this situation. The first of these liquors passes to the state of gas at the temperature of 35 degrees; the second, at that of 80 (of Reaumur).

Some fluids require a stronger heat for this purpose ; such as water, the sulphuric and nitric acids, oil, &c.

To convert water into an æriform fluid, Messrs. De la Place and Lavoisier filled a glass vessel with mercury, and reversed it over a dish filled with the same metal. Two ounces of water were transferred beneath this vessel ; and the mercury was heated to the temperature of between ninety-five and a hundred of Reaumur, by plunging it in a boiler filled with the mother water of nitre. The included water became rarefied, and occupied the whole capacity.

Water, by passing through earthen vessels ignited in the fire, becomes converted into gas, according to Priestley and Kirwan. The æoli-pile, the steam-engine, the digester of Papin, and the process of the glass-blowers, who blow large globes by injecting a mouthful of water through

through their iron tube, prove the conversion of water into gas.

It follows from these principles, that the volatilization of water being nothing more than a direct combination of caloric with this liquid, the portions of water which are the most immediately exposed to heat, must be the first volatilized: and this is daily observed; for it is continually seen that ebullition begins at the part most heated. But when the heat is applied equally at all parts, the ebullition is general.

Several phenomena have led us to believe that water may be converted into air. The process of the glass-blowers to blow large spheres; the hydraulic organ of father Kircher; the phenomena of the æolipile; the experiments of Messrs. Priestley and Kirwan; the manner of assisting combustion, by sprinkling a small quantity of water upon the coals—all these circumstances appeared to announce the conversion of water into air. But it was far from being supposed that most of these phenomena were produced by the decomposition of this fluid; and the genius of Mr. Lavoisier was necessary to carry this point of doctrine to the degree of certainty and precision, which in my opinion it now appears to possess.

Messrs. Macquer and De la Metherie had already

already observed, that the combustion of inflammable air produced much water. Mr. Cavendish confirmed these experiments in England, by the rapid combustion of inflammable air and vital air. But Messrs. Lavoisier, De la Place, Monge, and Meusnier, have proved that the whole mass of the water might be converted into hydrogen and oxygen; and that the combustion of these two gases produced a volume of water proportioned to the weight of the two principles employed in this experiment.

1. If a small glass vessel be inverted over mercury, and a known quantity of distilled water and filings of iron be put into the upper part of this vessel, inflammable air will be gradually disengaged, the iron will rust, and the water which moistens it will diminish, and at length disappear; the weight of the inflammable air which is produced, and the augmentation in weight of the iron, will be equivalent to the weight of the water made use of. It appears therefore to be proved, that the water is reduced into two principles, the one of which is inflammable air, and the other is the principle which has entered into combination with the metal. Now we know that the oxidation or calcination of metals is owing to vital air; and consequently the two substances produced, namely

namely the vital air and inflammable air, arise from the decomposition of water.

2. When water is converted into the state of vapour, in its passage through an ignited iron tube, the iron becomes oxidized, and hydrogen is obtained in the state of gas. The augmentation of weight in the metal, and the weight of the hydrogen obtained, form precisely a sum equal to that of the water employed.

The experiment made at Paris, in the presence of a numerous commission of the Academy, appears to me to leave no further doubt concerning the decomposition of water.

A gun-barrel was taken, into which a quantity of thick iron wire, flattened by hammering, was introduced. The iron and the gun-barrel were weighed: the gun-barrel was then covered with a lute proper to defend it from the contact of the air; it was afterwards placed in a furnace, and inclined in such a manner as that water might run through it. At its most elevated extremity was fixed a funnel designed to contain water, and to let it pass drop by drop by means of a cock: this funnel was closed, to avoid all evaporation of the water. At the other extremity of the gun-barrel was placed a tubulated receiver, intended to receive the water which might pass without decomposition;
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and to the tubulure of the receiver the pneumato-chemical apparatus was adapted. For greater precaution, a vacuum was made in the whole apparatus before the operation began. Lastly, as soon as the gun-barrel was red-hot, the water was introduced drop by drop. Much hydrogenous gas was obtained: and at the end of the experiment the gun-barrel was found to have acquired weight; and the flat pieces of iron included within were converted into a stratum of black oxide of iron, or Ethiops martial, crystallized like the iron ore of the island of Elba. It was ascertained that the iron was in the same state as that which is burned in oxygenous gas; and the increased weight of the iron, added to that of the hydrogen, was accurately equal to that of the water employed.

The hydrogenous gas obtained was burned with a quantity of vital air equal to that which had been retained by the iron, and the six ounces of water were recomposed.

3. Messrs. Lavoisier and De la Place, by burning in a proper apparatus a mixture of fourteen parts of hydrogenous gas, and eighty-six of oxigene, obtained a proportionate quantity of water. Mr. Monge obtained the same result at Mezieres, at the same time.

The most conclusive and the most authentic

experiment which was made upon the composition or synthesis of water, is that which was begun on the 23d of May, and ended on the 7th of June, 1788, at the Royal College, by Mr. Lefevre de Gineau.

The volume of oxygenous gas consumed, when reduced to the pressure of twenty-eight inches of mercury, at the temperature of ten degrees of the thermometer of Reaumur, was 35085 (French) cubic inches, and its weight 250 gros 10,5 grains.

The volume of hydrogenous gas was 74967,4 cubic inches, and the weight 66 gros 4,3 grains.

The nitrogenous gas and the carbonic acid which were mixed with these gases, and which had been extracted out of the receiver at nine several times, weighed 39,23 grains.

The oxygenous gas contained $\frac{1}{38}$ of its weight of carbonic acid; so that the weight of the gases burned was 280 gros 63,8 grains, which makes 2 pounds 3 ounces 0 gros 63,8 grains.

The vessels were opened in the presence of the gentlemen of the Academy of Sciences, and several other learned men, and were found to contain 2 pounds 3 ounces 0 gros 33 grains of water: this weight answers to that of the gases made use of, wanting 31 grains; this deficiency may

may arise from the caloric which held the gases in solution being dissipated when they became fixed, which must necessarily have occasioned a loss.

The water was subacid to the taste, and afforded $27\frac{1}{2}$ grains of nitric acid, which acid is produced by the combination of the nitrogen and oxygen gases.

From the experiment of the decomposition of water, 100 parts of this fluid contained

Oxigene $84,2636 = 84\frac{1}{2}$.

Hydrogene $15,7364 = 15\frac{1}{2}$.

According to the experiment of its composition, 100 parts of water contained

Oxigene $84,8 = 84\frac{1}{2}$.

Hydrogene $15,2 = 15\frac{1}{2}$.

Independent of these experiments of analysis and synthesis, the phenomena exhibited by water, in its several states, confirm our ideas with regard to the constituent parts which we acknowledge it to possess. The oxidation of metals in the interior parts of the earth, at a distance from the atmospherical air, the efflorescence of pyrites, and the formation of ochres, are phenomena which cannot be explained without the assistance of this theory.

Water, being composed of two known principles, must act like all other compound bodies

which we know; that is, according to the affinities of its constituent parts. It must therefore in some instances yield its hydrogene, and in others its oxigene.

If it be placed in contact with bodies which have the strongest affinity with oxigene, such as the metals, oils, charcoal, &c. the oxigenous principle will unite with these substances; and the hydrogenæ, being set at liberty, will be dissipated. This happens when hydrogen gas is disengaged, by causing the acids to act upon certain metals; or when red-hot iron is plunged in water, as Messrs. Haffenfratz, Stouffz, and D'Hellancourt have observed.

In vegetables, on the contrary, it seems that the hydrogen is the principle which fixes itself; while the oxigene is easily disengaged, and makes its escape.

SECTION VIII.

Concerning the Combinations of Nitrogene Gas, 1. With Hydrogene Gas. 2. With the Earthy Principles forming the Alkalis.

IT appears to be proved, that the combination of nitrogene gas with hydrogene forms one of the substances comprised in the class of alkalis. It is very probable that the others are composed of this same gas and an earthy basis. It is from these considerations that we have thought proper to place those substances here: and we have adopted that decision with so much the more foundation, because the knowledge of alkalis is indispensably necessary to enable us to proceed with order in a course of chemistry; and because these re-agents are most frequently employed, and their combinations and uses present themselves at every step in the phenomena of nature and art.

It is an established convention to call every substance an Alkali, which is characterised by the following properties:

A. An acrid, burning, urinous taste.

B. The property of converting syrup of violets green; but not the tincture of turnsole, as certain authors announce.

C. The

C. The virtue of forming glafs, when fufed with quartzofe fubftances.

D. The faculty of rendering oils mifcible with water; of effervefcing with certain acids; and of forming neutral falts with all of them.

I muft obferve that none of thefe characters is rigorous and exclufive; and that confequently no one of them is fufficient to afford a certainty of the exiftence of an alkali: but the reunion of feveral forms, by their concurrence, a mafs of proofs or indications, which lead us to fufficient evidence.

The alkalis are divided into fixed alkalis and volatile alkalis. This diftinction is eftablifhed upon the fmell of thefe fubftances: the former are not volatilized, even in the focus of the burning mirror, and emit no characteristic fmell; whereas the latter are eafily reduced into vapour, and emit a very penetrating odour.

CHAP. I.

Concerning Fixed Alkalis.

NO more than two kinds of fixed alkalis have hitherto been difcovered: the one which is called Vegetable Alkali, or Pot-Afh; the other Mineral Alkali, or Soda.

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ARTICLE I.

Concerning the Vegetable Alkali, or Pot-Ash.

This alkali may be extracted from various substances; and it is more or less pure, accordingly as it is afforded by one substance or another. Several varieties are made in commerce, to which different names have been affixed, and which are indispensably necessary to be known. The chemist may indeed confound all these distinctions, in his writings, under one single denomination: but the distinctions established by the artists are founded upon a series of experiments, which have proved that the virtues of these several alkalis are very different; and this constant variety in their effects appears to me to justify the various denominations assigned to them.

1. The alkali extracted from the lixivium of wood-ashes, is known by the name of *Salin*. The *salin* calcined, and by this means disengaged from all the blackening principles, forms pot-ash.

The ashes are more or less rich in alkali, according to the nature of the wood which affords them; in general, hard woods contain the most. The ashes of beech afford from 11 to 13lb. per quintal,

quintal, according to the experiments which I have made in the large way, at St. Sauveur; those of box afforded from 12 to 14lb. The tables drawn up by the several administrators of the gunpowder and saltpetre manufactories may be consulted, respecting the quantity of alkali afforded by the combustion of several plants: they used 4000lb. of each in their various experiments.

To extract this alkali, nothing more is necessary than to wash the ashes, and to concentrate the dissolution in boilers of cast iron. It is on account of the alkali that wood ashes are employed in the lixiviums used by laundresses or bleachers. The use of alkali, in this case, is to combine with the fat substances, and to render them soluble in water.

Almost all the pot-ash sold in commerce for the use of our glass-houses, our soap-makers, our bleaching-grounds, &c. is fabricated in the north, where the abundance of wood admits of its being applied to this single purpose. We might establish works of this kind to sufficient advantage in the forests of our kingdom. But there is more to be done than is generally supposed, before the inhabitants of the mountains can be turned towards this species of industry. I have experienced this difficulty in the attempts
and

and very considerable sacrifices which I have made to secure this resource in the neighbourhood of Laigoual and Lesperou. The accurate calculations which I have made, have nevertheless proved that the pot-ash would cost only from 15 to 17 livres the quintal, whereas we purchase that from the north at 30 or 40 livres.

2. The lees of wine is almost totally converted into alkali by combustion. This alkali is called *Cendres Gravelées*: it has almost always a greenish colour. This alkali is considered as very pure.

3. The combustion of tartar of wine likewise affords an alkali of considerable purity. It is usually burned wrapped up in paper, in small packets, which are dipped in water, and afterwards exposed upon burning coals. In order to purify it, the residue of the combustion is dissolved in water, the solution concentrated by fire, the foreign salts separated in proportion as they precipitate; and a very pure alkali is at last obtained, which is known by the name of Salt of Tartar.

To procure salt of tartar more speedily, as well as more economically, I burn a mixture of equal parts of nitrate of pot-ash, or common nitre

nitre and tartar. The residue, after lixiviation, affords a beautiful salt of tartar.

Salt of tartar is the alkali most commonly employed in medical uses; it is given in the dose of several grains.

4. If saltpetre be fused upon charcoal, the acid is decomposed and dissipated, while the alkali remains alone and disengaged: this is called Extemporaneous Alkali.

When the vegetable alkali has been brought to the greatest state of purity, it attracts the humidity of the air, and is resolved into a liquor. In this state it is known by the very improper name of Oil of Tartar per Deliquium.

ARTICLE II.

Concerning the Mineral Alkali, or Soda.

The Mineral Alkali has been so called, because it forms the basis of marine salt.

It is obtained from marine plants by combustion: for this purpose heaps of the saline plants are formed; and at the side of these heaps a round cavity is dug, which is enlarged towards the bottom, and is three or four feet in depth: this is the fire-place in which the vegetables are burned. The combustion is kept up without interrup-

interruption for several days; and when all the plants are consumed, a mass of alkaline salt is found remaining, which is cut into pieces, to facilitate its carriage and sale. This is known by the name of Rock Soda, or Soda.

All marine plants do not afford soda of the same quality. The barilla of Spain affords the beautiful soda of Alicant. I am assured that we might cultivate it upon our coasts in the Mediterranean, with the greatest success. This culture is highly interesting to the arts and commerce; and government ought to encourage this new species of industry. But an individual, however inclined or devoted to the public good, might make vain efforts to appropriate this commerce to our advantage, if he were not powerfully assisted by government; because the Spanish ministry has prohibited the exportation of the seed of barilla, under the strongest penalties. In Languedoc, and in Provence, we cultivate on the banks of our ponds a plant known by the name of Salicor, which affords soda of a good quality; but the plants which grow without cultivation produce an inferior sort. I have made an accurate analysis of each species, the results of which may be seen at the article *Verrerie* of the *Encyclopedie Methodique*.

The mineral alkali is cleared of all heterogeneous

geneous salts by dissolving it in water, and separating the several salts in proportion as they fall down. The last portion of the fluid being concentrated affords the soda, which crystallizes in rhomboidal octahedrons.

The mineral alkali is sometimes found in a native state: in Egypt it is known by the name of Natron. The two lakes of Natron described by Sicard and Mr. Volney, are situated in the desert of Chaiat, or St. Macaire, to the west of Delta. Their bed is a natural cavity of three or four leagues in length, and a quarter of a league in breadth; the bottom is solid and stony. It is dry during nine months in the year; but in winter a water of a violet-red colour oozes out of the earth, which fills the lake to five or six feet in depth: the return of the heat of summer evaporates this, and leaves a bed of salt behind it of two feet in thickness, which is dug out with bars of iron. The quantity obtained annually amounts to 36,000 quintals.

Mr. Proust found natron upon the schisti which form the foundation of the town of Angers; the same chemist likewise found it upon a stone from the salpetriere of Paris.

The mineral alkali differs from the vegetable, because—1. It is less caustic. 2. It is so far

far from attracting humidity, that it effloresces in the air. 3. It crystallizes in rhomboidal octahedrons. 4. It forms different products with the same bases. 5. It is more proper for vitrification.

Do the alkalis exist ready formed in vegetables, or are they the product of the several operations made use of in extracting them?—This question has divided the opinions of chemists. Du Hamel and Grosse proved, in 1732, the existence of alkali in cream of tartar, by treating it with the same nitric, sulphuric, and other acids. Margraff has given additional proofs of this, in a Memoir which forms the twenty-fifth of his collection. Rouelle read a Memoir to the Academy on the 14th of June, 1769, upon the same subject: he even affirms that he was acquainted with this truth before the work of Margraff appeared.—See the *Journal de Physique*, vol. i.

Rouelle, and the marquis De Bullion, proved that tartar exists in must.

It must not be concluded from the existence of an alkali in vegetables, that this salt is there found in a disengaged state. On the contrary, it is found combined with acids, oils, &c.

The alkalis, such as we have described them, even after they have been disengaged from
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every mixture, by solution, filtration, and evaporation, are not nevertheless in that state of purity and disengagement, which is necessary to be obtained in many cases: they are nearly in the state of neutral salts, by their combination with the carbonic acid. When it is required to disengage this acid, the alkali must be dissolved in water, and quick-lime then slaked in the solution. This substance seizes the carbonic acid of the alkali, and gives out its caloric in exchange. We shall speak of the circumstances of this operation when we shall have occasion to treat of lime. The alkali being deprived of the carbonic acid, no longer effervesces with other acids; it is more caustic, and more violent in its action; unites more easily to oils; and is then called Caustic Alkali, Pure Pot-ash, or Pure Soda.

When this alkali is evaporated, and brought into the dry form, it is known by the name of *Lapis Causticus*. The corrosive virtue of this substance depends principally upon the avidity with which it seizes humidity, and falls into deliquium.

The caustic alkali, as it is usually prepared, always contains a small quantity of carbonic acid, siliceous earth, iron, lime, &c. Mr. Berthollet has proposed the following means of purifying

purifying it:—He concentrates the caustic lixivium until it has acquired a slight degree of consistence; at which period he mixes it with alcohol, and draws off a portion by distillation. As soon as the retort is become cold, he finds it to contain crystals, mixed with a blackish earth, in a small quantity of liquor of a dark colour, which is separated from the solution of alkali in the alcohol, which swims above like an oil. These crystals consist of the alkali saturated with the carbonic acid, and are insoluble in spirit of wine; the deposition consists of filiceous earth, lime, iron, &c.

The caustic alkali in a state of great purity, dissolved in the alcohol, swims above the aqueous solution which contains the effervescent alkali. If the spirituous solution of alkali be concentrated on the sand-bath, transparent crystals are formed, which consist of the pure alkali itself; these crystals appear to be formed by quadrangular pyramids inserted one in another; they are very deliquescent, are soluble in water and in alcohol, and produce cold by their solution.—See the *Journal de Physique*, 1786, page 401.

The alkalis we have just spoken of, combine easily with sulphur.

This combination may be effected—1. By the fusion

fusion of equal parts of alkali and sulphur.
 2. By digesting the pure and liquid alkali upon sulphur.—In these cases the alkali becomes of a reddish-yellow colour.

The solutions of sulphur in alkali are known by the name of Livers of Sulphur, Sulphures of Alkali, &c. They emit an offensive smell, resembling that of rotten eggs. This is occasioned by the escape of the stinking gas, called Hepatic Gas.

The sulphur may be precipitated by acids; and the result of this precipitation is what the ancient chemists distinguished by the name of Milk of Sulphur, and Magistery of Sulphur.

These sulphures or hepars dissolve metals. Gold itself may be so divided by this means as to pass through filters. Stahl has supposed that Moses made use of this method to enable the Israelites to drink the golden calf.

Though the analysis of the two alkalis has not been made with strictness, several experiments lead us to believe that nitrogene is one of their principles. Mr. Thouvenel, having exposed washed chalk to the exhalations of animal substances in putrefaction, obtained nitrate of pot-ash, or common nitre. I have repeated this experiment in a closed chamber of six feet square. Twenty-five pounds of chalk washed in warm water, and exposed to the exhalation of
 bullock's

bullock's blood in putrefaction during eleven months, afforded nine ounces of nitrate of lime, in a dried state; and three ounces one gros of crystals of nitrate of pot-ash, or common nitre.

The repeated distillation of soaps decomposes them, and affords ammoniac. Now the analysis of this last, by Mr. Berthollet, proves the existence of nitrogenous gas as one of its constituent parts. There is therefore room to apprehend that nitrogeous gas is one of the principles of alkalis.

The experiments of Mr. Thouvenel, as well as my own, lead me to believe that this gas, when combined with lime, forms pot-ash, or the vegetable alkali; while its union with magnesia forms soda. This last opinion is supported by the experiments—1. Of Dehne, who obtained magnesia from soda (see Cresset's Chemical Annals, 1781, page 53). 2. Of Mr. Deyeux, who obtained similar results even before Mr. Dehne. 3. Of Mr. Lorgna, who obtained much magnesia by dissolving, evaporating, and calcining soda repeatedly (Journal de Physique, 1787). Mr. Osburg confirmed these various experiments in 1785.

C H A P. II.

Concerning Ammoniac, or the Volatile Alkali.

OUR researches have not hitherto exhibited more than one species of volatile alkali. Its formation appears to be owing to putrefaction; and though the distillation of *some* schisti affords it, yet this circumstance may be attributed to their origin, which is pretty generally ascribed to vegetable and animal decomposition. We find frequently enough, in these substances, the print of fishes, which is in favour of this opinion. Some plants likewise afford volatile alkali; for which reason they have been called Animal Plants. But the volatile alkali is more especially afforded by animal substances: the distillation of all their parts affords it in considerable abundance. Horns are employed in preference, because they are resolved almost entirely into oil and volatile alkali. The putrefaction of all animal substances produces volatile alkali; and in this case, as well as in distillation, it is formed by the combination of its two constituent parts: for the analysis very often fails in exhibiting any alkali ready

ready formed, in such parts as distillation or putrefaction would abundantly afford it from.

Almost all the volatile alkali made use of in commerce or medicine, is afforded by the decomposition of sal ammoniac. It is even on account of this circumstance that the chemists who have drawn up the New Nomenclature have distinguished the volatile alkali by the name of Ammoniac.

To obtain ammoniac in a state of considerable purity, equal parts of sifted quick-lime and muriate of ammoniac, or common sal ammoniac in powder, are mixed. This mixture is then introduced into a retort, to which a receiver and the apparatus of Woulfe have been adapted. A quantity of pure water is to be put into the bottles, correspondent to the weight of the salt employed; and the junctures of the vessels are made good with the usual lutes. The ammoniac is disengaged in the state of gas, at the first impression of the fire. It combines with the water with heat; and when the water of the first bottle is saturated, the gas passes to that of the second, and saturates it in its turn.

Volatile alkali is known by its very strong but not disagreeable smell. It is easily reducible into the state of gas, and preserves this form at the temperature of the atmosphere. This gas

may be obtained by decomposing the muriate of ammoniac by quick-lime, and receiving the product over mercury.

Alkaline gas kills animals, and corrodes the skin. The irritation is such, that I have seen pimples arise all over the bodies of some birds exposed to its atmosphere.

This gas is improper for combustion; but if a taper be gently immersed in it, the flame is enlarged before it goes out, and the gas suffers a decomposition. Alkaline gas is lighter than atmospheric air, and has even been mentioned, on account of its lightness, as a proper substance to fill balloons. The count De Milly proposed to place a brazier, or vessel containing fire, under the balloon, to keep the gas in its greatest state of expansibility.

The experiments of Dr. Priestley, who changed alkaline gas into hydrogen gas by means of the electric spark; those of the chevalier Laudriani, who, by passing the same gas through ignited glass tubes, obtained a large quantity of hydrogenous gas—occasioned a suspicion of the existence of hydrogen among the principles of alkaline gas. But the experiments of Mr. Berthollet have removed all doubts on this subject; and all observations appear to unite in authorising us to consider this alkali

as a compound of the nitrogenous and hydrogenous gases.

1. If the oxygenated muriatic acid be mixed with very pure ammoniac, an effervescence takes place, with a disengagement of nitrogenous gas, a production of water, and a conversion of the oxygenated acid into the ordinary muriatic acid. In this beautiful experiment, the water which is produced is formed by the combination of the hydrogen of the alkali and the oxygen of the acid; and the nitrogen gas being set at liberty, is dissipated.

2. When the nitrate of ammoniac is exposed to distillation, nitrogen gas is obtained, and a greater quantity of water is found in the receiver than the salt itself contained. After the operation, the ammoniac is found no longer to exist. The water of the receiver is slightly charged with a small quantity of nitric acid, which had passed over. In this case, the hydrogen of the alkali, and the oxygen of the acid, form the water in the receiver, while the nitrogenous gas escapes.

If the oxides of copper or gold be heated with ammoniacal gas, the product is water and nitrogenous gas, and the metals are reduced.

I have observed that the oxides of arsenic, being digested with ammoniac, are reduced,
and

and often form octahedral crystals of arsenic. In this case there is a disengagement of nitrogen gas, and a formation of water.

It very often happens when metals, such as copper or tin, are dissolved by means of the nitric acid, that an absorption of air takes place, instead of a disengagement of nitrous gas, as might be expected: I have seen several persons very much embarrassed in such cases, and I have often been so myself. This phenomenon takes place more especially when a very concentrated acid is made use of, and the copper is in fine filings: in this case ammoniac is produced. I have shewn this fact to my auditors long before I was acquainted with the theory of its formation. That which led me to suspect its existence, was the blue colour which the solution takes in this case. This ammoniac is produced by the combination of the hydrogen of the water with the nitrogen gas of the nitric acid; while the oxygen of the same acid, and that of the water, oxidized the metal, and prepared it for solution. It is to a similar cause that we must refer the experiment of Mr. John Michael Hauffman of Colmar, who by passing nitrous gas through a certain quantity of precipitate of iron, in the mercurial apparatus, observed that this gas was speedily absorbed, and
the

the colour of the iron changed; at the same time that vapour of ammoniac was found in the vessels. It is by a similar theory we may account for the formation of alkaline gas, by the mixture of hepatic gas and nitrous gas over mercury, as Mr. Kirwan observes.

Mr. Austin formed ammoniac; but he observed that the combination of nitrogenous gas with the base of hydrogene does not take place, unless this last is in a state of great condensation.

The formation of ammoniac by distillation and putrefaction, appears to me likewise to indicate its constituent parts. In fact, there is in both these operations a disengagement of hydrogene and nitrogene gas, and their combination produces ammoniac.

Mr. Berthollet has proved, by the way of decomposition, that one thousand parts of ammoniac, by weight, are composed of about eight hundred and seven of nitrogene gas, and one hundred and ninety-three of hydrogene gas. — See the collection of the Royal Academy, 1784, page 316.

According to Dr. Austin, the nitrogene gas is in proportion to the hydrogene, as one hundred and twenty-one to thirty-two.

SECTION IX.

Concerning the Combination of Oxigene
with certain Bases forming Acids.

IT appears to be out of doubt, that the bodies which we are agreed to call Acids, are combinations of vital air with a certain elementary substance. The analysis of almost all the acids, whose component parts are known, establishes this truth in a positive manner; and it is on account of this property that the denomination of Oxigenous Gas has been given to vital air.

Every substance which possesses the following properties is called an Acid :

A. The word *sour*, which is usually employed to denote the impression or lively and sharp sensation produced on the tongue by certain bodies, may be regarded as synonymous to the word *acid*. The only difference which may be established between them is, that the one denotes a weak sensation, whereas the other comprehends all the degrees of force from the least perceptible taste to the greatest degree of causticity. We say that verjuice, gooseberries, or lemons, are *sour*; but we use the word *acid* to express the impression which the nitric, sulphuric, or muriatic acids make upon the tongue.

The

The causticity of acids appears to arise from their strong tendency to combination; and it is from this property that the immortal Newton has defined them to be bodies which attract and are attracted.

It is also from this property that certain chemists have supposed acids to be pointed bodies.

On account of this decided tendency to combination which acids possess, it seldom happens that we find them in a disengaged state.

B. A second property of acids is that of changing certain blue vegetable colours into red, such as the colour of turnsole, syrup of violets, &c. These two re-agents are commonly used to ascertain the presence of acids.

The tincture of turnsole is prepared by lightly infusing in water that substance which is known in common under the name of Turnsole or Litmus. If the water be too lightly charged with the colouring matter, the infusion has a violet tinge, and must in that case be diluted with water until it becomes blue. The tincture of turnsole, when exposed to the sun, becomes red, even in closed vessels; and some time afterwards the colouring part is disengaged, and falls down in the form of a mucilaginous discoloured substance. Alcohol may be used instead of water in the preparation of this tincture.

It

It is generally supposed that the turnsole fabricated in Holland is nothing more than the colouring matter extracted from the rags or cloths of turnsole of Grand-Galargues, and precipitated upon a marly earth. These rags are prepared by impregnating them with the juice of nightshade (*morelle*), and exposing them to the vapour of urine, which develops their blue colour. The rags are sent into Holland, which has given rise to the opinion that they are used in the fabrication of turnsole; but subsequent enquiries have taught me that these cloths are sent to the dealers in cheese, who extract a colour by infusion, and wash their cheeses with it, to give them a red colour. I am convinced by the analysis of turnsole, that the colouring matter is of the same nature as that of archil (*orseille*); and that this principle is fixed on a calcareous earth, and a small quantity of pot-ash. In consequence of this analysis, I have endeavoured to cause the liken *parellus* of Auvergne to ferment with urine, lime, and alkali; and I obtained a paste similar to that of turnsole. The addition of alkali appears to me to be necessary to prevent the development of the red colour, which, when combined with the blue, forms the violet of the archil.

When any concentrated acid is to be tried
with

with syrup of violets, there are two particulars to be attended to. 1. The syrup of violets is often green, because the petal of the violet contains a yellow part at its base, which, when combined with the blue, forms this green colour: it is therefore essential to employ only the blue of the petal in order to have a beautiful blue infusion. 2. Care must be taken to dilute the syrup with a certain quantity of water; because otherwise concentrated acids, such as the sulphuric, would burn it, and form a coal.

The simple infusion of violets may be used instead of the syrup.

The colouring matter of indigo is not sensible to the impression of acids. The sulphuric acid dissolves it without altering the colour.

C. A third character of acids is, they effervesce with alkalis; but this property is not general. 1. Because the carbonic acid, and almost all weak acids, cannot be distinguished by this property. 2. Because the purest alkalis combine with acids, without motion or effervescence.

Is there not one single acid in nature, of which the others may be only modifications?

Paracelsus admitted an universal principle of acidity, which communicated taste and solubility to all its compounds.

Becher believed that this principle was composed

posed of water and vitrifiable earth. Stahl endeavoured to prove that the sulphuric acid was the universal acid; and his opinion was adopted by most chemists for a long time.

Long after the time of Stahl, Meyer maintained that the acid element was contained in fire. This system, which is founded on certain known facts, has had its supporters.

The chevalier Landriani imagined he had succeeded in reducing all the acids to the carbonic acid; because, by treating them all with different substances, he obtained this last as the constant result of his analysis. He was led into an error, for want of having sufficiently attended to the decomposition of the acids he made use of, and the combination of their oxigene with the carbone of the bodies which entered into his experiments, and produced the carbonic acid.

Lastly, the strict analysis and synthesis of most of the known acids, have proved to Mr. Lavoisier that oxigene is the base of all of them; and that their differences and varieties arise only from the substance with which this common principle is combined.

Oxigene united with metals forms oxides; and among these last there are some which possess acid characters, and are classed amongst acid substances.

Oxigene

• Oxigene combined with inflammable substances, such as sulphur, carbone, and oils, forms other acids.

• The action of acids upon bodies in general cannot be understood but by founding our explanations upon the data which we have established respecting the nature of their constituent parts.

• The adhesion of oxigene to the base is more or, less strong in the several acids, and consequently their decomposition is more or less easy; as, for example, in metallic solutions; which do not take place excepting when the metal is in the state of an oxide. The acid which will yield its oxigene with the greatest facility to oxidize the metal, will have the most powerful action upon it. Hence it happens, that the nitre and the nitro-muriatic acids are those which dissolve metals the most readily; and hence likewise it happens that the muriatic acid dissolves the oxides more easily than the metals, while the nitric acid acts contrariwise: hence also it arises that this last acts so powerfully upon oils, &c.

• It is impossible to conceive and explain the various phenomena presented to us by acids in their operations, if we have no idea of their constituent principles. Stahl would not have believed in the formation of sulphur, if he had
under-

understood the decomposition of the sulphuric acid upon charcoal; and if we except the combinations of acids with alkalis, and with certain earths, these substances are either totally or partially decomposed in all the operations made with them upon metals, vegetables, and animals, as we shall find by observing the phenomena exhibited in these cases respectively.

We shall at present treat only of some of the acids; and shall direct our attention to the others in proportion as we shall have occasion to treat of the various substances which afford them: we shall attend in preference to those which are the best known, and which have the greatest influence in the operations of nature, as well as in those of our laboratories.

C H A P. I.

Concerning the Carbonic Acid.

THIS acid is almost always observed in the state of gas. We find that the ancients were in some measure acquainted with it. Van Helmont called it Gas Silvestre, the gas of must, or of the vintage. Becher himself had a considerably accurate notion of it, as appears by the fol-

following passage: "Distinguitur autem inter
" fermentationem apertam et clausam, in apertâ
" potus fermentatus sanior est, sed fortiori in
" clausâ: causa est, quod evaporantia rarefacta
" corpuscula, imprimis magna adhuc silvestri-
" um spirituum copia, de quibus antea egimus;
" retineatur, et in ipsum potum se precipitet,
" unde valde eum fortiorem reddit."

Hoffmann attributed the virtue of most mi-
neral waters to an elastic spirit contained in
them.

Mr. Veneſ, a celebrated professor in the
schools at Montpellier, proved in 1750 that
the waters of Seltzer owed their virtue to a
superabundant portion of air.

In 1755, Dr. Black of Edinburgh advanced
that lime-stone contains much air of a different
nature from common air. He affirmed that the
disengagement of this air converted it into lime;
and that by the restoration of this air calcareous
stone was regenerated. In the year 1746, Dr.
McBride supported this doctrine with new facts.
Mr. Jacquin, professor of Vienna, resumed the
same pursuit, multiplied experiments on the
manner of extracting this air, and added other
proofs in confirmation that the absence of the
air rendered alkalis caustic, and formed lime.
Dr. Priestley exhibited all the perspicuity and
pre-

precision on this subject which might be expected from his abilities, and his skill in making experiments of this kind. This substance was then known by the name of Fixed Air. In 1772, Bergmann proved that it is an acid, which he called by the name of Aerial Acid. Since the time of this celebrated chemist, it has been distinguished by the names of Mephitic acid, Cretaceous acid, &c. and as soon as it was proved to consist of a combination of oxygen and carbone, or pure charcoal, the name of Carbonic acid was appropriated to it.

The carbonic acid is found in three different states. 1. In that of gas. 2. In a state of mixture. 3. In a state of combination.

It is found in the state of gas at the Grotto del Cano, near Naples; at the well of Perols, near Montpellier; in that of Negrac in Vivarais; upon the surface of the Lake Averno in Italy, and on those of several springs; in various subterraneous places, such as tombs, cellars, necessaries, &c. It is disengaged in this form by the decomposition of vegetables heaped together, by the fermentation of wine or beer; by the putrefaction of animal matters, &c.

It exists in the state of simple mixture in mineral waters, since in these it possesses all its acid properties.

It

It exists in a state of combination in lime-stone, common magnesia, alkalis, &c.

Various processes are employed to collect it, according to the state in which it is found.

I. When the carbonic acid exists in the state of gas, it may be collected—1. By filling a bottle with water, and emptying it into the atmosphere of this gas; the acid takes the place of the water, and the bottle is afterwards corked to retain it. 2. By exposing lime-water, caustic alkalis, or even pure water, in its atmosphere: the gaseous acid mixes or combines with these substances; and may be afterwards extracted by re-agents, which we shall proceed to describe.

II. When the carbonic acid exists in a state of combination, it may be extracted—1. By distillation with a strong heat. 2. By the reaction of other acids, such as the sulphuric acid, which has the advantage of not being volatile, and consequently is not altered by its mixture with the carbonic acid which is disengaged.

III. When the carbonic acid exists in the state of simple mixture, as in water, brisk wines, &c. it may be obtained—1. By agitation of the liquid which contains it; as Mr. Venel practised, by making use of a bottle to which he adapted a moistened bladder.

2. By distillation of the same fluid.—These two first methods are not accurate.

3. The process indicated by Mr. Gioanetti, consists in precipitating the carbonic acid by means of lime-water, weighing the precipitate, and deducting thirteen thirty-second parts for the proportion of carbonic acid; it having been deduced from analysis, by this celebrated physician, that thirty-two parts of carbonate of lime contain seventeen lime, two water, and thirteen acid.

This substance is an acid, as is proved—

1. Because tincture of turnsole, agitated in a bottle filled with this gas, becomes red. 2. Ammoniac, or volatile alkali, poured into a vessel filled with the gas, is neutralized. 3. Water impregnated with this gas is strongly sub-acid. 4. It neutralizes alkalis, and causes them to crystallize.

It remains at present to examine the properties of this acid gas.

A. It is unfit for respiration. History informs us that two slaves whom Tiberius caused to descend into the Grotto del Cano, were immediately stifled; and two criminals that Peter de Toledo caused to be shut in there, suffered the same fate. The abbé Nollet, who had the courage to respire the vapour, perceived a suffocating sensation, and a slight degree of acidity, which produced coughing and sneezing. Pila-

tre

and do Rosier, who presents himself to our notice on all occasions wherein danger was to be faced, caused himself to be fastened by cords fixed under his arms, and descended into the gaseous atmosphere of a hock of beer in fermentation. He had scarcely entered into the mephitic before slight prickings obliged him to shut his eyes; a violent suffocation prevented him from respiring; he felt a giddiness, accompanied with those noises which characterize the apoplexy: and when he was drawn up, his sight remained dim for several minutes; the blood had filled the jugulars; his countenance had become purple; and he neither heard nor spoke but with great difficulty: all these symptoms however disappeared by degrees.

It is this gas which produces the many unhappy accidents at the opening of cellars, in places where wine, cyder, or beer are suffered to ferment. Birds plunged in the carbonic acid gas, suddenly perish. The famous Lake of Averno, where Virgil placed the entrance of hell, exhales so large a quantity of carbonic acid, that birds cannot fly over it with impunity. When the waters of Bouldou or Perols are dry, such birds as attempt to quench their thirst in the delfs, are enveloped in the mephitic vapour, and die.

Frogs, plunged in an atmosphere of carbonic acid, live from forty to sixty minutes, by suspending their respiration.

Insects are rendered torpid after a certain time of remaining in this air; but they resume their liveliness the moment they are exposed to the free air.

Bergmann pretended that this acid suffocates by extinguishing irritability; he founds his opinion upon the circumstance of his having taken out the heart of an animal which had died in the carbonic acid, before it was cold, and it exhibited no sign of irritability. The chevalier Landriani has proceeded still further; for he affirms that this gas extinguishes irritability, even when applied to the skin; and has asserted that, by tying a bladder full of this gas to the neck of a fowl, in such a manner that the head only of the animal was in the open air, and the whole body enveloped in the bladder, the fowl immediately perished. The abbé Fontana has repeated and varied this experiment on several animals, none of which died.

The count Morrozzo published experiments made in the presence of Dr. Cigna; the results of which appear to invalidate the consequences of the celebrated Bergmann: but it is to be observed, that the chemist of
Turin

Turin caused his animals to die only in air vitiated by the death of another animal; and that in this circumstance the nitrogene gas predominates.—See the *Journal de Physique*, tom. xxv. p. 112.

B. The carbonic acid is improper for vegetation. Dr. Priestley having kept the roots of several plants in water impregnated with the carbonic acid, observed that they all perished; and in those instances where plants are observed to vegetate in water or in air which contains this gas, the quantity of gas is very small.

Mr. Senebier has even observed, that plants which are suffered to grow in water slightly acidulated with this gas, emit a much larger quantity of oxygenous gas; because, in this case, the acid is decomposed, the carbonaceous principle combines and is fixed in the vegetable, while the oxigene is thrown off.

I have observed that those fungi which are formed in subterraneous places, are almost totally resolved into carbonic acid; but if these vegetables be gradually exposed to the action of light, the proportion of acid diminishes; while that of the coaly principle augments, and the vegetable becomes coloured. I have pursued these experiments with the greatest care in a coal mine.

C. The

C. The carbonic acid is easily dissolved in water. Water impregnated with this acid possesses very valuable medicinal qualities; and several apparatus have been successively invented to facilitate this mixture. The apparatus of Nooth, improved by Parker and Magellan, is one of the most ingenious. On this subject the *Encyclopédie Méthodique* may be consulted, article *Acide Mephitique*.

The natural acidulous mineral waters do not differ from these, excepting in consequence of their holding other principles in solution; and they may be perfectly imitated when their analysis is well known. It is absurd to think that art is incapable of imitating nature in the composition of mineral waters. It must be admitted that the processes of nature are absolutely unknown to us, in all the operations which relate to life; and we cannot flatter ourselves with the hope of imitating her in these circumstances. But when the question relates to an operation purely mechanical, or consisting of the solution of certain known principles in water, we can and ought to perform it even still better, as we have the power of varying the doses, and proportioning the efficacy of any artificial mineral water to the purposes to which it is intended to be applied.

D. The

D. The carbonic acid gas is heavier than common air. The proportion between these two airs in weight, according to Mr. Kirwan, is 45,69 to 68,74. The proportion, according to the experiments of Mr. Lavoisier, is 48,81 to 69,50.

This considerable weight causes it to occupy the lowest situations; and even gives it the property of being poured out from one vessel to another, so as to displace the atmospheric air. This truly curious phenomenon was observed by Mr. De Sauvages, as may be seen in his Dissertation upon Air, which was crowned in Marseilles in 1750.

It appears to be proved, by sufficient experiments, that the carbonic acid is a combination of carbone, or pure charcoal, and oxigene.

1. The oxides of mercury, when distilled, are reducible without addition, and afford only oxigenous gas; but if a small quantity of charcoal be mixed with the oxide, the product which comes over consists of carbonic gas only, and the weight of the charcoal is diminished.

2. If well-made charcoal be ignited, and plunged into a vessel filled with oxigenous gas, and the vessel be instantly closed, the charcoal burns rapidly, and at last goes out: the product in this experiment is carbonic acid,
which

which may be separated by the known processes; the remainder is a small quantity of oxygenous gas, which may be converted into carbonic acid by the same treatment.

In these experiments I see nothing but charcoal and oxygenous gas: and the consequence deduced is simple and natural.

The proportion of charcoal is to that of oxygen as 12,0288 to 56,687.

When the carbonic acid, in some cases, is obtained by burning hydrogenous gas, it arises from carbone held in solution in this gas. The carbone may even be dissolved in hydrogenous gas, by exposing it to the focus of the burning mirror in the mercurial apparatus, under a glass vessel filled with this gas.

The hydrogenous gas which is extracted from a mixture of sulphuric acid and iron, holds more or less of charcoal in solution; because iron itself contains this substance in a greater or less quantity, as is ascertained by the fine experiments of Messrs. Berthollet, Monge, and Vander Monde.

The alkalis, such as we usually meet with them, contain carbonic acid; and it is this acid which modifies them, and diminishes their energy, at the same time that it communicates to them the property of effervescing. We may therefore

therefore consider alkalis as carbonates with excess of alkali; and it is easy to saturate this superabundant alkali, and to form true crystallizable neutral salts.

ARTICLE I.

Carbonate of Pot-ash.

The carbonate of pot-ash was formerly distinguished by the name of Cretaceous Tartar. The method of causing oil of tartar to crystallize, has long been known. Bonhius and Montet have successively shewn these processes: but the simplest consists in exposing an alkaline solution in an atmosphere of the acid gas which is disengaged in the vinous fermentation; the alkali becomes saturated, and forms tetrahedral prismatic crystals terminated by very short four-sided pyramids.

I have several times obtained those crystals in the form of quadrangular prisms, with their extremities cut off slantwise.

This neutral salt no longer possesses the urinous taste of the alkali, but exhibits the penetrating taste of neutral salts, and may be employed in medicine with the greatest success. I have been a witness to its being taken in the dose of one dram (gros) without the least inconvenience.

This

This salt possesses an advantage beyond the salt of tartar, in being less caustic, and always of the same virtue.

It contains, according to the analysis of Bergmann, twenty parts acid, forty-eight alkali, and thirty-two water, in the quintal.

It does not attract the humidity of the air. I have preserved some of it for several years in a capsule, without any appearance of alteration.

The carbonate of pot-ash is decomposed by fire in a sufficient heat, which occasions a considerable boiling or ebullition. The residue is glass, in which the alkali is in the caustic state. Lime decomposes the carbonate, by uniting to the acid; and acids produce the same effect, by combining with the alkaline bases.

ARTICLE II.

Carbonate of Soda.

The denominations of Aërated Mineral alkali, Cretaceous Soda, &c. have been successively given to this kind of carbonate.

The mineral alkali, in its natural state, contains a greater quantity of carbonic acid than the vegetable; and nothing more is necessary than to dissolve it, and duly evaporate the water, in order to obtain it in crystals.

These

These crystals are usually rhomboidal octahedrons; and sometimes have the form of rhomboidal laminæ, applied obliquely one upon the other, so that they resemble tiles.

This carbonate effloresces in the air.

One hundred parts contain sixteen parts acid, twenty alkali, and sixty-four water.

The affinity of its basis with silica is stronger than that of the carbonate of pot-ash; in consequence of which, the vitrification it produces is more quick and easy.

Lime and the acids decompose it, with the same phenomena which we have observed at the article Carbonate of Pot-ash.

ARTICLE III.

Carbonate of Ammoniac.

This salt has been generally known by the name of Concrete Volatile Alkali. It has likewise been distinguished by that of Cretaceous Volatile Alkali, &c.

It may be obtained by distillation from many animal substances. Tobacco affords, likewise, a large proportion; but almost the whole of that which is employed in the arts, and in medicine, is formed by the direct combination of the carbonic acid and ammoniac, or volatile alkali.

kali. This combination may be effected—1. By passing the carbonic acid through ammoniac, or the pure volatile alkali in solution. 2. By exposing ammoniac in an atmosphere of carbonic acid gas. 3. By decomposing the muriate of ammoniac by the neutral salts which contain this acid, such as the carbonate of lime or common chalk. For this purpose, white chalk is taken, and very accurately dried; and then mixed with equal parts of muriate of ammoniac, or common sal ammoniac in fine powder. This mixture is put into a retort, and distilled; the ammoniac and the carbonic acid being disengaged from their bases, and reduced into vapours, combine together, and are deposited on the sides of the receiver, where they form a stratum more or less thick.

The crystallization of this carbonate appeared to me to be that of a four-sided prism, terminated by a dihedral summit.

The carbonate has less smell than the ammoniac; it is very soluble in water. Cold water dissolves its own weight of this salt, at the temperature of sixty degrees of Fahrenheit.

One hundred grains of this salt contain forty-five parts acid, forty-three alkali, and twelve water, according to Bergmann.

Most acids decompose it, and displace the carbonic acid.

CHAP. II.

Concerning the Sulphuric Acid.

SULPHUR, like every other combustible substance, cannot be burnt but by virtue of the oxygenous gas which combines with it.

The most usual phenomena which accompany this combustion, are, a blue flame, a whitish and suffocating vapour, and a strong, penetrating, and disagreeable smell.

The results of this combination vary according to the proportion in which these two principles enter into this same combination.

The sulphureous or the sulphuric acid may be at pleasure obtained from sublimed sulphur, or from crude sulphur, accordingly as a greater or less quantity of oxygen is combined with the sulphur, by means of combustion.

When the current of air which maintains the combustion is rapid, the sulphur is carried, and deposited without any apparent alteration, into the internal part of the leaden chambers in which the oil of vitriol is made. If the current of air be rendered more moderate, the combination is somewhat more accurate; the sulphur
is

is partly changed, and is deposited in a pellicle upon the surface of the water. This pellicle is flexible like a skin, and may be handled and turned over in the same manner. If the current be still less rapid, and the air be suffered to have a sufficient time to form an accurate combination with the sulphur, the result is sulphurous acid; which acid preserves its gaseous form at the temperature of the atmosphere, and may become liquid like water by the application of cold, according to the fine experiments of Mr. Monge. If the combustion be still slower, and the air be suffered to digest upon the sulphur a longer time, and with greater accuracy, the result is sulphuric acid: this last combination may be facilitated by the mixture of saltpetre, because this substance furnishes oxygen very abundantly.

Numerous experiments which I have made in my manufactory, to economize the saltpetre employed in the fabrication of oil of vitriol, have several times exhibited the results here mentioned.

All the processes which are capable of being adapted for extracting the sulphuric acid, are reducible to—1. The extraction of it from substances which contain it. 2. Its direct formation by combination of sulphur and oxygen.

In

In the first case, the sulphures, or vitriolic salts of iron, copper, or zinc, and even those whose bases are clay and lime, according to Neumann and Margraff, may be exposed to distillation. But these expensive processes are not very easy to be carried into execution; and accordingly they have been abandoned, to make room for others of greater simplicity.

In the second case, the oxigene may be presented to the sulphur in two forms: either in the state of gas, or in the concrete state.

1. The combustion of sulphur by oxigenous gas, is performed in large chambers lined with lead. The combustion is facilitated by mixing about one-eighth of a nitrate of pot-ash with the sulphur. The acid vapours which fill the chamber are precipitated against its sides, and the condensation is facilitated by a stratum of water disposed on the bottom of the chamber. In some manufactories in Holland, this combustion is performed in large glass balloons with large mouths, and the vapours are precipitated upon water placed at the bottom.

In both cases, when the water is sufficiently impregnated with acid, it is concentrated in leaden boilers, and rectified in glass retorts, to render it white, and to concentrate it sufficiently for the purposes of trade. The acid, when of a
due

due strength, indicates sixty-six degrees, according to the acrometer of Mr. Baumé; and when it has not been carried to this degree, it is unfit for most of the uses for which it is intended. It cannot, for example, be employed in dissolving indigo; for the small quantity of nitric acid which it contains, unites with the blue of the indigo, and forms a green colour. I have ascertained this phenomenon by very accurate experiments; and I have been a witness to the failing of colours, and the loss of stuffs, in consequence of the imperfection of the acid.

2. When the oxigene in the concrete state is presented to the sulphur, it is then in combination with other bodies, which it abandons to unite with this last. This happens when the nitric acid is distilled from sulphur. Forty-eight ounces of this acid, at thirty-six degrees, distilled from two ounces of sulphur, afforded near four ounces of good sulphuric acid. This fact was known to Matte Lafaveur: but I pointed out all the phenomena and circumstances of the operation in 1781.

Sulphur may likewise be converted into sulphuric acid by means of the oxygenated muriatic acid.—*Encyclopédie Méthodique*, tom. i. p. 370.

The sulphuric acid which is found disengaged
in

in some places in Italy, appears likewise to arise from the combustion of sulphur. Baldassari has observed it in this state in a hollow grotto, in the midst of a mass of incrustations deposited by the baths of Saint Philip, in Tuscany. He asserts that the sulphureous vapour continually arises in this grotto. He likewise found sulphureous and vitriolic effervescences at Saint Albino, near mount Pulciano; and at the lakes of Travale, where he observed the branches of a tree covered with concretions of sulphur and the oil of vitriol.—*Journal de Physique*, t. vii.

P. 395.

O. Vandelli relates that, in the environs of Sienna and Viterbo, sulphuric acid is sometimes found dissolved in water. Mr. (the commander) De Dolomieu affirms that he found it pure and crystallized in a grotto of mount Etna, from which sulphur was formerly obtained.

According to a first experiment of Mr. Berthollet, sixty-nine parts of sulphur with thirty-one parts of oxigene formed one hundred parts of sulphuric acid; and, according to a second experiment, seventy-two of sulphur and twenty-eight of oxigene formed one hundred parts of dry acid.

The various degrees of concentration of the sulphuric acid have caused it to be distinguish-

ed by different names, under which it is known in commerce. Hence the denominations of Spirit of Vitriol, Oil of Vitriol, and Glacial Oil of Vitriol, to express its degrees of concentration.

The sulphuric acid is capable of passing to the concrete state by the impression of intense cold. This congelation is a phenomenon long since known. Kunckel and Bohn have spoken of it: and Boerhaave says expressly, "*Oleum vitrioli, summa arte purissimum, summo frigore hiberno in glebas solidescit perspicuas: sed, statim ac acuties frigoris retunditur, liquefcit et diffluit.*"—We are indebted to the Duke D'Ayen for some very valuable experiments upon the congelation of this acid; and Mr. De Morveau repeated them with equal success in 1782, and proved that this congelation may be affected at a degree of cold considerably less than what had been mentioned*.

I have already several times obtained beautiful crystals of sulphuric acid in flattened hexahedral prisms, terminated by an hexahedral pyramid; and my experiments have enabled me to conclude—1. That the very concen-

* See also the experiments of Mr. Keir, and the late experiments of Mr. Cavendish, on the congelation of acids, in the Philosophical Transactions.

trated

trated acid crystallizes more difficultly than that whose density lies between sixty-three and sixty-five. 2. That the proper degree of cold is from 1 to 3 degrees below 0 of Reaumur. The detail of my experiments may be seen in the volume of the Academy of Sciences of Paris for the year 1784.

The characters of the sulphuric acid are the following.

1. It is unctuous and fat to the touch, which has occasioned it to obtain the very improper name of Oil of Vitriol.

2. It weighs one ounce and seven gros in a bottle containing one ounce of distilled water.

3. It produces heat, when mixed with water, to such a degree as to exceed that of boiling water. If one end of a tube of glass be closed, and water poured into it, and the closed end of this tube be plunged into water, the water in the tube may be made to boil by pouring sulphuric acid into the external water which surrounds the tube.

4. It seizes with great avidity all inflammable substances; and it is blackened and decomposed by this combination.

Stahl supposed the sulphuric acid to be the universal acid. He founded this opinion more especially upon the circumstance, that cloths

soaked in a solution of alkali, and exposed to the air, attracted an acid which combined with the alkali; and formed a neutral salt, by him supposed to be of the nature of sulphate of pot-ash, or vitriolated tartar. Subsequent and more accurate experiments have shewn that this aerial acid was the carbonic; and the present state of our knowledge is such as permits us still less than ever to believe in the existence of an universal acid.

ARTICLE I.

Sulphate of Pot-ash.

The sulphate of pot-ash is described indifferently under the names of Arcanum Duplicatum, Sal de Duobus, Vitriolated Tartar, Vitriol of Pot-ash, &c.

This salt crystallizes in hexahedral prisms, terminating in hexahedral pyramids, with triangular faces.

It has a lively and penetrating taste, and melts difficultly in the mouth.

It decrepitates on hot coals, becomes red-hot before it fuses, and is volatilized without decomposition.

It is soluble in sixteen parts of cold water, at the temperature of 60 deg. of Fahrenheit; and boiling water dissolves one-fifth of its weight.

100 grains

100 grains contain 30.21 acid, 64.61 alkali, and 5.18 water.

Most of the sulphate of pot-ash used in medicine is formed by the direct combination of the sulphuric acid and pot-ash, or the vegetable alkali; but that which is met with in commerce is produced in the distillation of aqua fortis, by the sulphuric acid: this has the form of beautiful crystals, and is sold in the Comtat Venaissin at forty or fifty livres the quintal. The analysis of tobacco has likewise afforded me this sulphate.

Mr. Baumé proved to the Academy, in 1760, that the nitric acid, assisted by heat, is capable of decomposing the sulphate of pot-ash. Mr. Cornette afterwards shewed that the muriatic acid possesses the same virtue; and I shewed, in 1780, that this acid may be displaced by the nitric acid, without the assistance of heat; though the sulphuric acid resumes its place when the solution is concentrated by heat.

ARTICLE II.

Sulphate of Soda.

This combination of the sulphuric acid and soda is still known under the names of Glauber's Salt,

Salt, Sal Admirabile, Vitriol of Soda, &c. This salt crystallizes in rectangular octahedrons, of a prismatic or cuneiform figure, of which the two pyramids are truncated near their basis.

It has a very bitter taste, and easily dissolves in the mouth.

It swells up upon heated coals, and boils, in consequence of the dissipation of its water of crystallization. After this water has been dispersed, there remains only a white powder, difficult of fusion, which is volatilized without decomposition by a strong heat.

By exposure to the air, it effervesces, loses its transparency, and is reduced to a fine powder.

Three parts of water, at 60 deg. of Fahrenheit's thermometer, dissolved one part of this salt; but boiling water dissolves its own weight.

100 grains of sulphate of soda contain 14 acid, 22 alkali, and 64 water.

It is formed by the direct combination of the two principles which contain it; but the tamarix gallica, which grows on the sea-coasts, contains so large a quantity, that it may be extracted to advantage. Nothing more is necessary for this purpose, than to burn the plant, and lixiviate the ashes. That salt which is sold in the south of France, in fine crystals, is prepared in this manner. It is very pure, and the price does
not

not exceed thirty or thirty-five livres the quintal. This sulphate is likewise formed in our laboratories when we decompose the muriate of soda, or common salt, by sulphuric acid.

Pot-ash dissolved by heat in a solution of sulphate of soda, precipitates the soda, and takes its place. See my Chemical Memoirs.

ARTICLE III.

Sulphate of Ammoniac.

The sulphate of ammoniac, commonly known by the name of Glauber's Secret Ammoniacal Salt, is very bitter.

It crystallizes in long flattened prisms with six sides, terminated by six-sided pyramids.

It cannot be obtained in well-formed crystals but by insensible evaporation.

It slightly attracts the humidity of the air.

It liquefies by a gentle heat, and rises over a moderate fire.

Two parts of cold water dissolve one of this salt; and boiling water its own weight, according to Fourcroy. The fixed alkalis, barytes, and lime, disengage the ammoniac from it.

The nitric and muriatic acids disengage the sulphuric acid.

The

The different substances of which we have treated are of considerable use in the arts and medicine.

The sulphureous acid is employed in whitening silk, and giving it a degree of lustre. Stahl had even combined it with alkali, and formed the salt so well known under the name of Stahl's Sulphureous Salt. This combination passes quickly to the state of sulphate, if it be left exposed to the air; as it speedily absorbs the oxygen which is wanting for that purpose.

The principal use of the sulphuric acid is in dyeing, in which art it serves to dissolve indigo, and carry it in a state of extreme division upon the stuffs to be dyed; it is likewise used by the manufacturers of Indians, or silk and stuff mixtures, to carry off the preparation of these goods, wherein lime is used. The chemist makes great use of this acid in his analyses; and to separate other acids from their combination, such as the carbonic, the nitric, and the muriatic acids.

The sulphate of pot-ash is known in medicine as an alterative, and is used in cases of lacteous coagulations. It is given in the dose of a few grains, and is even purgative in a greater dose.

The sulphate of soda is an effectual purgative in the dose of from four to eight gros, or drams.

drams. For this purpose it is dissolved in a pint of water.

CHAP. III.

Concerning the Nitric Acid.

THE nitric acid, called Aqua Fortis in commerce, is lighter than the sulphuric. It usually has a yellow colour, a strong and disagreeable smell, and emits red vapours. It gives a yellow colour to the skin, to silk, and to almost all animal substances with which it may come in contact. It dissolves and speedily corrodes iron, copper, zinc, &c. with the escape of a cloud of red vapours during the whole time its action lasts. It entirely destroys the colour of violets, which it reddens. It unites to water with facility; and the mixture assumes a green colour, which disappears when still further diluted.

This acid has been no where found in a disengaged state. It always exists in a state of combination; and it is from these combinations that the art of chemistry extracts it, to apply it to our uses. The nitrate of pot-ash, or common nitre, is the combination which is best known,

known, and is likewise that from which we usually extract the nitric acid.

The process used in commerce to make aqua fortis, consists in mixing one part of saltpetre with two or three parts of red bolar earth. This mixture is put into coated retorts, disposed in a gallery or long furnace, to each of which is adapted a receiver. The first vapour which arises in the distillation is nothing but water, which is suffered to escape at the place of juncture, before the luting; and when the red vapours begin to appear, the phlegm which is condensed in the receiver is poured out; and the receiver, being replaced, is carefully luted to the neck of the retort. The vapours which are condensed, form at first a greenish liquor: this colour disappears insensibly, and is replaced by another which is more or less yellow. Some chemists, more especially Mr. Baumé, were of opinion that the earth acted upon the saltpetre by virtue of the sulphuric acid it contains. But not to mention that this principle does not exist in all the earths made use of, as Messrs. Macquer, De Morveau, and Scheele have proved, we know that pulverized flints equally produce the decomposition of saltpetre. I am therefore of opinion that the effect of these earths upon the salt ought to be referred to the
very

very evident affinity of the alkali to the flex, which is a principal component part; and more especially to the slight degree of adhesion which exists between the constituent principles of nitrate of pot-ash.

We decompose saltpetre in our laboratories by means of the sulphuric acid. Very pure nitrate of pot-ash is taken, and introduced into a tubulated retort, placed in a sand bath, with a receiver adapted. All the places of junction are carefully luted; and as much sulphuric acid as amounts to half the weight of the salt is poured through the tubulure; and the distillation is proceeded upon. Care is taken to fit a tube into the tubulure of the receiver; the other end of which is plunged into water, to condense the vapours, and to remove all fear of an explosion.

Instead of employing the sulphuric acid, we may substitute the sulphate of iron, and mix it with saltpetre in equal parts. In this case the residue of the distillation, when well washed, forms the mild earth of vitriol made use of to polish glafs.

Stahl and Kunckel have spoken of a very penetrating aqua fortis, of a blue colour, obtained by the distillation of nitre with arsenic.

Whatever precaution is taken in the purification of the saltpetre, and however great the
attention

attention may be which is bestowed upon its distillation, the nitric acid is always impregnated with some foreign acid, either the sulphuric or muriatic, from which it requires to be purified. It is cleared of the first by re-distilling it upon very pure saltpetre, which retains the small quantity of sulphuric acid that may exist in the mixture. It is deprived of the second by pouring into it a few drops of a solution of nitrate of silver. The muriatic acid combines with the silver, and is precipitated with it in the form of an insoluble salt. The fluid is then suffered to remain at rest, and is afterwards decanted from the precipitate or deposition. This acid, so purified, is known under the name of *Aqua Fortis* for Parting, Precipitated Nitrous Acid, Pure Nitric Acid, &c.

Stahl had considered the nitric acid as a modification of the sulphuric, produced by its combination with an inflammable principle. This opinion has been supported by several new facts, in a dissertation of Mr. Pietsch, crowned by the Academy of Berlin in 1749.

The experiments of the celebrated Hales led him still nearer to this conclusion, as his manipulations were successively employed upon the two constituent principles of the nitric acid. This celebrated philosopher had obtained
 ninety

ninety cubic inches of air from half a cubic inch of nitre; and he proceeded no further in his conclusions, than to assert that this air is the principal cause of the explosions of nitre.

The same philosopher relates that the pyrites of Walton, treated with equal quantities of spirit of nitre and water, produce an air which has the property of absorbing the fresh air, which may be made to enter the vessel. This great man, therefore, extracted successively the two principles of the nitric acid; and these capital experiments put Dr. Priestley in the road to the discoveries he has since made.

It was not however until the year 1776 that the analysis of the nitric acid was well known. Mr. Lavoisier, by distilling this acid from mercury, and receiving the several products in the pneumato-chemical apparatus, has proved that the nitric acid, whose specific gravity is to that of distilled water as 131607 to 100000, contains—

	oz.	gros.	grains.
Nitrous gas	1	7	$51\frac{1}{4}$
Oxygenous gas	1	7	$7\frac{1}{2}$
Water	13	—	—

By combining these three principles together the decomposed acid was regenerated.

The action of the nitric acid on most inflammable

mable matters, consists in nothing more than a continual decomposition of this acid.

If the nitric acid be poured upon iron, copper, or zinc, these metals are instantly attacked with a strong effervescence; and a considerable disengagement of vapours takes place, which become of a red colour by their combination with the atmospheric air, but which may be retained and collected in the state of gas in the hydro-pneumatic apparatus. In all these cases the metals are strongly oxidized.

The nitric acid, when mixed with oils, renders them thick and black, converts them into charcoal, or inflames them, accordingly as the acid is more or less concentrated, or in a greater or less quantity.

If very concentrated nitric acid be put into an apothecary's phial, and be poured upon charcoal in an impalpable powder, and very dry, it sets it on fire instantly, at the same time that carbonic acid and nitrogene gas are disengaged.

The various acids which are obtained by the digestion of the nitric acid on certain substances, such as the oxalic acid, or acid of sugar, the arsenical acid, &c. owe their existence merely to the decomposition of the nitric acid, the oxigene of which is fixed in combination
with

with the bodies upon which this acid is decomposed, renders it one of the most active; because the action of acids upon most bodies is a consequence of their own proper decomposition.

The characters of nitrous gas, which is extracted by the decomposition of the acid, are—
1. It is invisible, or perfectly transparent. 2. Its specific gravity is rather less than that of atmospherical air. 3. It is unfit for respiration, though the abbé Fontana pretends that he respired it without danger. 4. It does not maintain combustion. 5. It is not acid, according to the experiments of the Duke de Chaulnes. 6. It combines with oxigene, and reproduces the nitric acid.

But what is the nature of this nitrous gas? It was at first pretended that it consists of the nitric acid saturated with phlogiston. This system ought to have been abandoned as soon as it was proved that the nitric acid deposited its oxigene upon the bodies on which it acted; and that the nitrous gas was less in weight than the acid made use of. A capital experiment of Mr. Cavendish has thrown the greatest light on the subject. This chemist having introduced into a tube of glass seven
parts

parts of oxygenous gas obtained without nitrous acid, and three parts of nitrogen gas; or, by estimating these quantities in weight, ten parts of nitrogen to twenty-six of oxygen—and having caused the electric spark to pass through this mixture, perceived that its volume or bulk was greatly diminished, and succeeded in converting it into nitric acid. It may be presumed, from his experiment, that the acid is a combination of seven parts of oxygen, and three of nitrogen. These proportions constitute the ordinary nitric acid; but when a portion of its oxygen is taken away, it passes to the state of nitrous gas; so that nitrous gas is a combination of nitrogen gas, with a small quantity of oxygen.

Nitrous gas may be decomposed by exposing it to a solution of the sulphur of pot-ash, or hear of sulphur: the oxygen gas unites to the sulphur, and forms sulphuric acid; while the nitrogen gas remains behind in a state of purity.

Nitrous gas may likewise be decomposed by means of pyrophorus, which burns in this air, and absorbs the oxygenous gas.

The electric spark has likewise the property of decomposing nitrous gas. Mr. Van Marum has observed that three cubic inches of the nitrous

trous gas are reduced by electricity to one cubic inch and three quarters; and that this residue no longer possessed any property of nitrous gas. Lastly, according to the experiments of Mr. Lavoisier, one hundred grains of nitrous gas contain thirty-two parts nitrogene, and sixty-eight parts oxigene: according to the same chemist, one hundred grains of nitric acid contain seventy-nine and a half oxigene and twenty and a half nitrogene; and this is the reason why nitrous gas should be employed in a less portion than nitrogene gas, to combine with the oxigene gas, and form the nitric acid.

These ideas upon the composition of the nitrous acid, appear to be confirmed by the repeated proofs we now have of the necessity of causing substances, which afford much nitrogene gas, to be presented to the oxigene gas, in order to obtain nitric acid.

The several states of the nitric acid may be clearly explained according to this theory:—
1. The fuming nitrous acid is that in which the oxigene does not exist in a sufficient proportion; and we may render the whitest and the most saturated nitric acid fuming and ruddy, by depriving it of a part of its oxigene by means of metals, oils, inflammable substances, &c., or even by disengaging the oxigene by

the simple exposition of the acid to the light of the sun, according to the valuable experiments of Mr. Berthollet.

The property which nitrous gas possesses, of absorbing oxigene to form the nitric acid, has caused it to be employed to determine the proportion of oxigene in the composition which forms our atmosphere. The abbé Fontana has constructed, on these principles, an ingenious eudiometer, the description and manner of using which may be seen in the first volume of Dr. Ingenhoufs's Experiments upon Vegetables.

Mr. Berthollet has very justly observed, that this eudiometer is inaccurate, or productive of deception—1. Because it is difficult to obtain nitrous gas constantly formed of the same proportions of nitrogene gas and oxigene; for they vary, not only according to the nature of the substances upon which the nitric acid is decomposed, but likewise accordingly as the solution of any given substance by the acid is made with greater or less rapidity. If the acid be decomposed upon a volatile oil, nothing but nitrogene gas can be obtained; if the acid act upon iron, and it be much concentrated, nitrogene gas only will be obtained, as I have observed, &c. 2. The nitric acid which is formed by the union of nitrous gas and oxigene, dissolves

solves a greater or less quantity of nitrous gas according to the temperature, the quality of the air which is tried, the size of the eudiometer, &c. so that the diminution varies in proportion to the greater or less quantity of nitrous gas obtained by the nitric acid which is formed: consequently the diminution ought to be greater in winter than in summer, &c.

According to the experiments of Mr. Lavoisier, four parts of oxygenous gas are sufficient to saturate seven parts and one-third of nitrous gas; whereas it is found that nearly sixteen parts of atmospheric air are required to produce the same effect: whence this celebrated chemist has concluded, that the air of the atmosphere does not in general contain more than one-fourth of oxygenous or respirable gas. Repeated experiments at Montpellier, upon the same principle, have convinced me that twelve or thirteen parts of atmospheric air are constantly sufficient to saturate seven parts and one-third of nitrous gas.

These experiments shew, to a certain degree of accuracy, the proportion in which vital air exists in the air which we respire; but they do not give us any information respecting the noxious gases which, when mixed with the atmospheric air, alter it, and render it unwholesome.

This observation very much curtails the use of this instrument.

The combination of the oxygenous and nitrous gases always leaves an æriform residue, which Mr. Lavoisier estimated at about one thirty-fourth of the whole volume : it arises from the mixture of the foreign gaseous substances, which more or less affect the purity of the gases made use of.

ARTICLE I.

Nitrate of Pot-ash.

The nitric acid, combined with pot-ash, forms the salt so well known under the names of Nitre, Saltpetre, Nitre of Pot-ash, &c.

This neutral salt is rarely the product of any direct combination of its two constituent parts. It is found ready formed in certain places ; and in this manner it is that the whole of the nitre employed in the arts is obtained.

In the Indies, it effloresces on the surface of uncultivated grounds. The inhabitants lixiviate these earths with water, which they afterwards boil and crystallize in earthen pots. Mr. Dombey has observed a great quantity of saltpetre near Lima, upon earths which serve for pasture.

pasture, and which produce only gramineous plants. Mr. Talbot Dillon, in his travels into Spain, relates that one-third of all the grounds; and in the southern parts of that kingdom even the dust of the roads, contain saltpetre.

Saltpetre is extracted in France from the ruins and plaster of old houses.

This salt exists ready formed in vegetables, such as parietaria and bugloss, &c. And one of my pupils, Mr. Virenque, has proved that it is produced in all extracts which are capable of fermenting.

The fermentation of saltpetre may be favoured, by causing certain circumstances to concur which are of advantage to its formation.

In the north of Europe, the saltpetre-beds are formed with lime, ashes, earth of uncultivated grounds, and straw, which are stratified, and watered with urine, dunghill-water, and mother waters. These beds are defended by a covering of heath or broom. In the year 1775, the King caused a prize to be proposed by the Royal Academy of Sciences at Paris, to discover a method of increasing the product of saltpetre in France, and to relieve the people from the obligation of permitting the saltpetre makers to examine their cellars, in order to discover and carry away saltpetre earths. Several Memoir

moirs were offered on the subject, which the Academy united into a single volume; and these have added to our knowledge, by instructing us more especially concerning the nature of the matters which favour the formation of nitre. It was known, for example, long since, that nitre is formed in preference near habitations, or in earths, impregnated with animal products: it was likewise known that, in general, the alkaline basis was afforded by the concurrence of a vegetable fermentation. Mr. Thouvenel, whose Memoir was crowned, has proved that the gas which is disengaged by putrefaction, is necessary for the formation of nitre; that blood, and, next to it, urine, were the animal parts which were the most favourable to its formation; that the most minutely divided and the lightest earths were the most proper for nitrification; that the current of air must be properly managed, to fix upon these earths the nitric acid which is formed, &c.

It seems to me that Becher possessed a considerably accurate knowledge of the formation of nitre, as appears from the following passages:

“Hæc enim (vermes, muscæ, serpentes) putrefacta in terram abeunt prorsus nitrosam;
 “ex qua etiam communi modo nitrum copiosum parari potest, sola elixatione cum aqua communi.”—*Phys. Subt. lib. i. S. V. t. i. p. 286.*

“Sed

“ Sed et ipsum nitrum necdum finis ultimus
“ putrefactionis est ; nam cum ejusdem partes
“ igneæ separantur, reliquæ in terram abeunt
“ prorsum puram et insipidam, sed singulari
“ magnetismo præditam novum spiritum aëre-
“ um attrahendi, rursusque nitrum fiendi.”—
Phys. Subt. S. V. t. i. p. 292.

From all the discoveries and observations which have been hitherto made, it follows that, in order to establish artificial nitre beds, it is necessary that animal putrefaction and vegetable fermentation should concur. The nitro-gene gas, in its disengagement from the animal substances, combines with the oxigene, and forms the acid, which again unites with the alkali, whose formation is favoured by the vegetable decomposition.

When the manufacturer is in possession of salt-petre grounds, whether by the simple operations of nature or by the assistance of art, the saltpetre is extracted by the lixiviation of these earths ; which lixivium is afterwards concentrated, and made to crystallize. In proportion as the evaporation goes forward, the marine salt, which almost always accompanies the formation of nitre, is precipitated. This is taken out with ladles, and set to drain in baskets placed over the boilers.

As

As a great part of the nitre has an earthy basis, and requires to be furnished with an alkaline basis to cause it to crystallize; this purpose is accomplished either by mixing ashes with the saltpetre earths, or by adding an alkali ready formed to the lixivium itself.

Nitre obtained by this first operation is never pure, but contains sea-salt, and an extractive and colouring principle, from which it must be cleared. For this purpose it is dissolved in fresh water, which is evaporated; and to which bullocks blood may be added, to clarify the solution. The nitre obtained by the second manipulation is known by the name of Nitre of the Second Boiling. If recourse be had to a third operation to purify it, it is then called Nitre of the Third Boiling.

The purified nitrate of pot-ash is employed in delicate operations, such as the manufacture of gunpowder, the preparation of aqua fortis for parting, and the solution of mercury, &c. The saltpetre of the first boiling is used in those works where aqua fortis is made for the dyers. It affords a nitro-muriatic acid, which is capable of dissolving tin by itself.

The nitrate of pot-ash crystallizes in prismatic octahedrons, which almost always represent six-sided flattened prisms, terminated by dihedral summits.

It

It has a penetrating taste, followed by a sensation of coldness.

It is fusible upon ignited coals ; and in this case its acid is decomposed. The oxygen unites with the carbone, and forms the carbonic acid ; the nitrogen gas and the water are dissipated ; and it is this mixture of principles which has been known under the name of *Clyffus of Nitre*.

The distillation of the nitrate of pot-ash affords twelve thousand cubic inches of oxygenous gas for each pound of the salt.

Seven parts of water dissolve one of nitre, at sixty degrees of Fahrenheit ; and boiling water dissolves its own weight of this salt.

One hundred grains of the crystals of nitre contain thirty acid, sixty-three alkali, and seven water.

When a mixture of equal parts of nitre and sulphur is thrown into a red-hot crucible, a saline substance is obtained, which was formerly called *Sal Polychrest of Glafer*, and which has since been considered as *Sulphate of Pot-ash*. If nitre be fused, and a few pinches of sulphur be thrown upon this salt in fusion, and the whole be afterwards poured out or cast into plates, it forms a salt known by the name of *Crystal Mineral*.

A mixture

A mixture of seventy-five parts of nitre, nine and a half of sulphur, and fifteen and a half of charcoal, forms gunpowder. This mixture is triturated from ten to fifteen hours, care being taken to moisten it from time to time. This trituration is usually performed by pounding mills, whose pestles and mortars are of wood. In order to give the powder the form proper to granulate it, it is passed through sieves of skin, whose perforations are of various sizes. The grained powder is then sifted, to separate the dust, and it is afterwards carried to the drying-house. Gunpowder for artillery, or cannon-powder, receives no other preparation; but it is necessary to glaze the powder which is intended for fowling. This last preparation is effected by putting it into a kind of cask which turns on an axis, and by whose movement the angles of the grains are broken, and their surfaces polished. We are indebted to Mr. Baumé and the chevalier Darcy for a series of experiments, in which they have proved—

1. That good gunpowder cannot be made without sulphur.
2. That charcoal is likewise indispensably necessary.
3. That the quality of gunpowder depends, *cæteris paribus*, upon the accuracy with which the mixture is made.

4. That

4. That the effect of powder is greater when simply dried than when it is granulated.

The effect of gunpowder depends upon the rapid decomposition which is made in an instant of a considerable mass of nitre, and the sudden formation of those gases which are the immediate product. Bernoulli, in the last century, ascertained the development of air by the deflagration of gunpowder: he placed four grains of powder in a recurved tube of glass, plunged the tube in water, and set fire to the gunpowder by means of the burning-glass; after the combustion the interior air occupied a larger space, so that the space abandoned by the water was such as would have contained two hundred grains of gunpowder.—Hist. de l'Académie des Sciences de Paris, 1696, t. ii. Mémoire de M. Varignon sur le Feu et la Flamme.

The fulminating powder, which is made by the mixture and trituration of three parts of nitre, two of salt of tartar, and one of sulphur, produces effects still more terrible. In order to obtain the full effect, it is exposed in a ladle to a gentle heat; the mixture melts, a sulphureous blue flame appears, and the explosion takes place. Care must be taken to give neither too strong nor too slight a degree of heat. In either case, the combustion of the principles takes place separately, and without explosion.

ARTI-

ARTICLE II.

Nitrate of Soda.

This salt has received the name of Cubic Nitre, on account of its form; but this denomination is not exact, because it affects a figure constantly rhomboidal.

It has a cool, bitter taste.

It slightly attracts the humidity of the air.

Cold water, at sixty degrees of Fahrenheit's thermometer, dissolves one-third of its weight; and hot water scarcely dissolves more.

It fuses upon burning coals with a yellow colour; whereas common nitre affords a white flame, according to Margraff—24 Dissert. sur le Sel Commun, t. ii. p. 343.

100 grains of this salt contain 28.80 acid, 50.09 alkali, and 21.11 water.

It is almost always the product of art.

ARTICLE III.

Nitrate of Ammoniac.

The vapours of ammoniac, or volatile alkali, being brought into contact with those of the nitrous

nitrous acid, combine with them, and form a white and thick cloud, which slowly subsides.

But when the acid is directly united to the alkali, the result is a salt, which has a cool, bitter, and urinous taste.

Mr. De Lisle pretends that it crystallizes in beautiful needles, similar to those of sulphate of pot-ash.

These crystals cannot be obtained but by a very slow evaporation.

When this salt is exposed to the fire, it liquefies, emits aqueous vapours, dries, and detonates.

Mr. Berthollet has analysed all the results of this operation, and has drawn from them a new proof of the truth of the principles which he has established with regard to ammoniac.

C H A P. IV.

Concerning the Muriatic Acid.

THIS acid is generally known by the name of Marine Acid, and it is still distinguished among artificers by the name of Spirit of Salt.

It is lighter than the two preceding acids; it has

has a strong penetrating smell, resembling that of saffron, but infinitely more pungent; it emits white vapours when it is concentrated; it precipitates silver from its solution in the form of an insoluble salt; &c. This acid has nowhere been found disengaged; and, to obtain it in this state, it is necessary to disengage it from its combinations. Common salt is usually employed for this purpose.

The spirit of salt of commerce is obtained by a process little differing from that which is used in the extraction of aqua fortis. But as this acid adheres more strongly to its basis, the product is very weak, and only part of the marine salt is decomposed.

Flints pulverized, and mixed with this salt, do not separate the acid. Ten pounds of flints in powder, treated by a violent fire with two pounds of the salt, did not afford me any other product than a mass of the colour of litharge. The fumes were not perceptibly acid. If clay, which has once served to decompose marine salt, be mixed with a new quantity of the same salt, it will not decompose an atom of it, even though the mixture be moistened and formed into a paste. These experiments have been several times repeated in my manufactory, and have constantly exhibited the same results.

The

The sulphate of iron, or martial vitriol, which so easily disengages the nitric acid, decomposes marine salt; but very imperfectly.

The impure soda known in France by the name of *Blanquette*, and in which my analysis has exhibited twenty-one pounds of common salt out of twenty-five, scarcely affords any muriatic acid when it is distilled with the sulphuric acid; but it affords abundance of sulphureous acid. Mr. Berard, director of my manufactory, attributed these results to the coal contained in this soda, which decomposed the sulphuric acid. He therefore calcined the *blanquette* to destroy the charcoal; and then he found he could treat it in the same manner as common salt, and with the same success.

The sulphuric acid is usually employed to decompose marine salt. My method of proceeding consists in drying the marine salt, pounding it, and putting it into a tubulated retort placed upon a sand bath. A receiver is adapted to the retort, and afterwards two bottles, after the manner of Woulfe, in which I distribute a weight of distilled water equal to that of the marine salt made use of. The joinings of the vessels are then luted, but with the greatest caution; and when the apparatus is thus fitted up, a quantity of sulphuric acid is poured

poured through the tubulure equal to half the weight of the salt. A considerable ebullition is immediately excited; and when this effervescence is slackened, the retort is gradually heated, and the mixture made to boil.

The acid is disengaged in the state of gas, and mixes rapidly with the water, in which it produces a considerable degree of heat.

The water of the first bottle is usually saturated with the acid gas, and forms a very concentrated and fuming acid; and though the second is weaker, it may be carried to any desired degree of concentration, by impregnating it with a new quantity of the gas.

The ancient chemists were divided respecting the nature of the muriatic acid. Becher supposed it to be the sulphuric acid modified by his mercurial earth.

This acid is susceptible of combining with an additional dose of oxigene; and, what is very extraordinary, it becomes more volatile in consequence of this additional quantity; whereas the other acids appear to acquire a greater degree of fixity in the same circumstances. It may even be said, that its acid virtues become weaker in this case, since its affinities with alkalis diminish; and it is so far from reddening blue vegetable colours, that it destroys them.

Another

Another phenomenon not less interesting, which is presented to us by this new combination, is, that though the muriatic acid seizes the oxigene with avidity, yet it contracts so weak a union with it, that it yields it to almost all bodies, and the mere action of light alone is sufficient to disengage it.

It is to Scheele that we are indebted for the discovery of the oxygenated muriatic acid. He formed it in the year 1774, by employing the muriatic acid as a solvent for manganese. He perceived that a gas was disengaged, which possessed the distinctive smell of aqua regia; and he was of opinion that in this case the muriatic acid abandoned its phlogiston to the manganese; in consequence of which notion he called it the Dephlogisticated Marine Acid. He took notice of the principal and truly astonishing properties of this new substance; and all chemists since his time have thought their attention well employed in examining a substance which exhibits such singular properties.

To extract this acid, I place a large glass alembic of one single piece upon a sand bath. To the alembic I adapt a small receiver; and to the receiver three or four small bottles nearly filled with distilled water, and arranged according to the method of Woulfe. I dispose the

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receiver

receiver and the bottles in a cistern, the places of junction being luted with fat lute, and secured with rags soaked in the lute of lime and white of egg. Lastly, I surround the bottles with pounded ice. When the apparatus is thus disposed, I introduce into the alembic half a pound of manganese of Cevennes, and pour upon it, at several repetitions, three pounds of fuming muriatic acid. The quantity of acid which I pour at once is three ounces; and at each time of pouring a considerable effervescence is excited. I do not pour a new quantity until nothing more comes over into the receivers. This method of proceeding is indispensably necessary, when the operator is desirous of making his process with a definite quantity of the materials. For if too large a quantity of acid be poured at once, it is impossible to restrain the vapours; and the effervescence will throw a portion of the manganese into the receiver. The vapours which are developed by the affusion of muriatic acid are of a greenish yellow colour; and they communicate this colour to the water when they combine with it. When this vapour is concentrated by means of the ice, and the water is saturated with it, it forms a scum at the surface, which is precipitated through the liquid, and resembles a congealed oil.

oil. It is necessary to assist the action of the muriatic acid by means of a moderate heat applied to the sand bath. The secure luting of the vessels is also an essential circumstance; for the vapour which might escape is suffocating, and would not permit the chemist to inspect his operation closely. It is easy to discover the place where it escapes through the lutes, by running a feather dipped in volatile alkali over them: the combination of these vapours instantly forms a white cloud, which renders the place visible where the vapour escapes. An excellent Memoir of Mr. Berthollet, published in the *Annales Chimiques*, may be consulted upon the oxygenated muriatic acid.

The same oxygenated muriatic acid may be obtained by distilling, in a similar apparatus, ten pounds of marine salt, three or four pounds of manganese, and ten pounds of sulphuric acid.

Mr. Reboul has observed that the concrete state of this acid is a crystallization of the acid, which takes place at three degrees of temperature below the freezing point of Reaumur. The forms which have been observed are those of a quadrangular prism, truncated very obliquely, and terminated by a lozenge. He has likewise observed hollow hexahedral pyramids on the surface of the liquor.

To make use of the oxygenated acid in the arts, and in order to concentrate a greater quantity in a given volume of water, the vapour is made to pass through a solution of alkali. A white precipitate is at first formed in the liquor; but a short time afterwards the deposition diminishes, and bubbles are disengaged, which are nothing but the carbonic acid. In this case two salts are formed, the oxygenated muriate, and the ordinary muriate. The mere impression of light is sufficient to decompose the former, and convert it into common salt. This lixivium contains, indeed, the oxygenated acid in a stronger proportion. The execrable smell of the acid is much weakened. It may be employed for various uses with the same success, and with great facility; but the effect is very far from corresponding with the quantity of oxygenated acid which enters into this combination, because the virtue of a great part is destroyed by its union with the alkaline basis.

The oxygenated muriatic acid has an excessively strong smell. It acts directly on the larynx, which it stimulates, excites coughing, and produces violent head-aches.

Its taste is sharp and bitter. It speedily destroys the colour of tincture of turnsole. But it appears that the property which most oxygenated

nated substances possess, of reddening blue colours, arises only from the combination of oxygen with the colouring principles; and that, when this combination is very strong and rapid, the colour is destroyed.

The oxygenated muriatic acid with which a solution of caustic alkali is saturated, affords, by evaporation in vessels secluded from the light, common muriate and oxygenated muriate. This last detonates upon charcoal; is more soluble in hot than in cold water; crystallizes, sometimes in hexahedral laminæ, and oftener in rhomboidal plates. These crystals have an argentine brilliancy, like mica. Its taste is faint; and its crystals, when they are dissolved in the mouth, produce a sensation of coolness resembling that of nitre.

Mr. Berthollet has ascertained, by delicate experiments, that the oxygenated muriatic acid which exists in the oxygenated muriate of potash, contains more oxygen than an equal weight of oxygenated muriatic acid dissolved in water; and this has led him to consider the oxygenated acid combined in the muriate as being super-oxygenated. He considers the common muriatic gas with relation to the oxygenated muriatic gas, the same as the nitrous gas or sulphureous gas with respect to the nitric and sulphuric acids.

acids. He pretends that the production of the simple muriate and the oxygenated muriate in the same operation, may be compared to the action of the nitric acid, which in many cases produces nitrate and nitrous gas. Hence he has considered the muriatic acid as a pure radical, which combined with a greater or less quantity of oxigene, forms either simple muriatic acid gas, or the oxygenated muriatic acid gas.

The oxygenated muriates of soda do not differ from those of pot-ash, but in being more deliquescent and soluble in alcohol, like all the salts of this nature.

The oxygenated muriate of pot-ash gives out its oxigene in the light, and by distillation as soon as the vessel is heated to redness. One hundred grains of this salt afford seventy-five cubic inches of oxigenous gas reduced to the temperature of twelve degrees of Reaumur. This air is purer than the others, and may be employed for delicate experiments. The oxygenated muriate of pot-ash, when crystallized, does not trouble the solutions of nitrate of lead, of silver, or of mercury.

Mr. Berthollet has fabricated gunpowder, by substituting the oxygenated muriate instead of saltpetre. The effects it produced were quadruple. The experiment in the large way, which

which was made at Effone, is but too well known, by the death of Mr. Le Tors and Mademoiselle Chevraud. This powder exploded the moment the mixture was triturated.

The oxigenated muriatic acid whitens thread and cotton. For this purpose the cotton is boiled in a weak alkaline lixivium; after which the stuff is wrung out, and steeped in the oxigenated acid. Care is taken to move the cloth occasionally in the fluid, and to wring it out. It is then washed in a large quantity of water, to deprive it of the smell with which it is impregnated.

I have applied this known property to the whitening of paper and old prints: by this means they obtained a whiteness which they never before possessed. Common ink disappears by this acid; but printers ink is not attacked by it.

Linen and cotton cloths, and paper, may be bleached by the vapour of the oxigenated marine acid. I have made some experiments in the large way, which have convinced me of the possibility of applying this method to the arts. The Memoir in which I have given an account of my experiments, will be printed in the volume of the Academy of Paris for the year 1787.

The oxigenated muriatic acid thickens oils;
and

and oxides metals to such a degree, that this process may be advantageously used to form verditer.

The oxygenated muriatic acid dissolves metals without effervescence; because its oxigene is sufficient to oxide them without the necessity of the decomposition of water, and consequently without the disengagement of gas.

This acid precipitates mercury from its solution, and converts it into the state of corrosive sublimate.

It converts sulphur into sulphuric acid, and instantly deprives the very black sulphuric acid of its colour.

When mixed with nitrous gas, it passes to the state of muriatic acid, and converts part of the gas into nitric acid.

When exposed to light, it affords oxygenous gas, and the muriatic acid is regenerated.

The muriatic acid acts very efficaciously upon metallic oxides, merely in consequence of its becoming oxygenated; and in this case it forms with them salts, which are likewise more or less oxygenated.

ARTICLE I.

Muriate of Pot-ash.

This salt is still distinguished by the name of Febrifuge Salt of Sylvius.

It has a disagreeable strong bitter taste.

It crystallizes in cubes, or in tetrahedral prisms.

It decrepitates upon coals ; and when urged by a violent heat it fuses, and is volatilized without decomposition.

It requires three times its weight of water, at the temperature of sixty degrees of Fahrenheit, for its solution.

It is subject to little alteration in the air.

One hundred grains of this salt contain 29.68 acid, 63.47 alkali, and 6.85 water. It is frequently met with, but in small quantities, in the water of the sea, in plaster, in the ashes of tobacco, &c. The existence of this salt in the ashes of tobacco might with justice have surprised me, as I had reason to expect the muriate of soda which is employed in the operation called watering. Was the soda metamorphosed into pot-ash by the vegetable fermentation ? This may be determined by direct experiments.

ARTI-

ARTICLE II.

Muriate of Soda.

The received names of Marine Salt, Common Salt, and Culinary Salt, denote the combination of muriatic acid with soda.

This salt has a penetrating but not bitter taste. It decrepitates on coals, fuses, and is volatilized by the heat of a glass-maker's furnace, without decomposition.

It is soluble in 2.5 times its weight of water, at sixty degrees of Fahrenheit's thermometer.

One hundred grains of this salt contain 33.3 acid, 50 of alkali, and 16.7 of water.

It crystallizes in cubes. Mr. Gmelin has informed us that the salt of the salt lakes in the environs of Sellen on the banks of the Caspian sea, forms cubical and rhomboidal crystals.

Mr. De Lisle observes, that a solution of marine salt, left to insensible evaporation during five years by Mr. Rouelle, had formed regular octahedral crystals resembling those of alum.

Marine salt may be obtained in octahedrons, by pouring fresh urine into a very pure solution of fresh salt. Mr. Berniard is convinced that this addition changed only the form of the salt, without altering its nature.

Common

Common salt is found native in many places. Catalonia, Calabria, Switzerland, Hungary, and Tyrol possess mines, which are more or less abundant. The richest salt mines are those of Wieliczka in Poland. Mr. Berniard has given us a description of them in the *Journal de Physique*; and Mr. Macquart, in his *Essays on Mineralogy*, has added interesting details concerning the working of these mines.

Our salt springs in Lorraine and Franche-comté, and some indications afforded by Bleton, have appeared sufficient motives to Mr. Thouvenel to presume that salt mines exist in our kingdom. This chemist expresses himself in the following manner :

“ At the distance of two leagues from Saverne, between the village of Huftenhausen and that of Garbourg, in a lofty mountain called Pensenperch, there are two great reservoirs of salt water; the one to the east, at the head of a large deep and narrow valley, which is called the great Limerthaal; the other to the west, upon the opposite slope, towards Garbourg. They communicate together by five small streams, which are detached from the upper reservoir, and unite in the lower one. From these two salt reservoirs flow two large streams; the upper runs into Franche-comté, and the lower into

into Lorraine, where they supply the well-known salt works."

The waters therefore flow to the distance of seventy leagues from the reservoir.

Salt mines appear to owe their origin to the drying up of vast lakes. The shells and madre-pores found in the immense mines of Poland are proofs of marine depositions. There are likewise some seas in which the salt is so abundant, that it is deposited at the bottom of the water; as appears from the analysis of the water of the lake Asphaltites, made by Messrs. Macquer and Sage.

This native salt is often coloured; and as in this state it possesses considerable brilliancy, it is called Sal-gem. It almost always contains an oxide of iron, which colours it.

As these salt mines are neither sufficiently abundant to supply the wants of the inhabitants of the globe, nor distributed with that uniformity as to permit all nations to have ready recourse to them, it has been found necessary to extract the salt from the water of the sea. The sea does not contain an equal quantity in all climates; Ingenhousz has shewn us that the northern seas contain less than the southern. Marine salt is so abundant in Egypt, that, according to Hasselquist, a fresh-water spring is a treasure

a treasure which is secretly transmitted from father to son.

The method of extracting the water of the sea varies according to the climates.

1. In the northern provinces, the salt sands of the sea coasts are washed with the least possible quantity of water, and the salt is obtained by evaporation.—See the description of this process by Mr. Guettard.

2. In very cold countries, salt water is concentrated by freezing, and the residue is evaporated by fire.—See Wallerius.

3. At the salt springs of Lorraine and Franche-comté, the water is pumped up, and suffered to fall upon heaps of thorns, which divide it, and cause a part to evaporate. The farther concentration is effected in boilers.

4. In the southern provinces, at Peccais, at Peyrat, at Cette, and elsewhere, the extraction is begun by separating a certain quantity of water from the general mass of the sea, which is suffered to remain in square spaces, called *Partenemens*. For this purpose it is necessary to have sluices which may be opened and shut at pleasure, and to form surrounding walls which prevent all communication with the sea, except by means of these gates. It is in the *partenemens* that the water goes through the
first

first stage of evaporation; and when it begins to deposit its salt, it is raised by bucket wheels to other square compartments, called Tables, where the evaporation finishes.

The salt is heaped together, to form the *cammelles*; in which state it is left for three years, in order that the deliquescent salts may flow out of it; and, after this interval of time, it is carried to market.

Exertions and enquiries have long since been made to discover a cheap method of decomposing marine salt, to obtain the mineral alkali at a low price, which is of such extensive use in the manufactures of soap, glass, bleaching, &c. The processes hitherto discovered are the following:

1. The nitric acid disengages the muriatic acid, and forms the nitrate of soda, which may be easily decomposed by detonation.
2. Pot-ash displaces the soda, even in the cold, as I found by experiment.
3. The sulphuric acid forms sulphate of soda by decomposing the marine salt; the new salt, when heated with charcoal, is destroyed; but a sulphure of soda, or liver of sulphur, is formed, which is difficult to be entirely separated; and this process does not appear to me to be economical. The sulphate may likewise be decomposed

posed by the acetite of barytes, and the soda afterwards obtained by calcination of the acetite of soda.

4. Margraff tried in vain to accomplish this purpose, by means of lime, serpentine, iron, clay, &c. He adds that if common salt be thrown upon lead heated to redness, the salt is decomposed, and muriate of lead is formed.

5. Scheele has pointed out the oxides of lead for the decomposition of common salt. If common salt be mixed with litharge, and made into a paste, the litharge gradually loses its colour, and becomes converted into a white matter, from which the soda may be extracted by washing. It is by processes of this kind that Turner extracts it in England; but this decomposition never appeared to me to be complete, unless the litharge was employed in a proportion quadruple to that of the salt. I have observed that almost all the bodies are capable of alkalizing marine salt, but that the absolute decomposition is very difficult.

6. Barytes decomposes it likewise, according to the experiments of Bergmann.

7. The vegetable acids, combined with lead, may likewise be used to decompose common salt. When these salts are mixed, a decomposition takes place: the muriate of lead falls
down;

down; and the vegetable acid, united to the soda, remains in solution. The vegetable acid may be dissipated by evaporation and calcination; and the alkali remains disengaged.

Marine salt is more especially employed at our tables, and in culinary purposes. It removes and corrects the insipidity of our food, and at the same time facilitates digestion. It is used in a large proportion to preserve flesh from putrefaction; but in a small dose it hastens that process, according to the experiments of Pringle, Macbride, Gardane, &c.

ARTICLE III.

Muriate of Ammoniac.

Of all the combinations of ammoniac this is the most interesting, and the most generally used. It is known by the name of Sal Ammoniac.

This salt may be directly formed by decomposing the muriate of lime by the means of ammoniac, as Mr. Baumé has practised at Paris. But almost all the sal ammoniac which circulates in commerce is brought to us from Egypt, where it is extracted by distillation from soot, by the combustion of the excrements of such animals as feed on saline plants.

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The details of the process which is used have not been very long known. One of the first writers who gave a description of this operation is father Sicard. He informed us, in 1716, that distilling vessels were charged with the foot of the excrements of oxen, to which sea salt and camels urine were added.

Mr. Lemairo, consul at Cairo, in a letter written to the Academy of Sciences in 1720, affirms that neither urine nor sea salt is added.

Mr. Hasselquist has communicated to the Academy of Stockholm a considerably extensive description of the process: by which we learn, that the dung of all animals which feed on saline plants is indiscriminately used, and that the foot is distilled, to obtain sal ammoniac.

The dung is dried by applying it against the walls; and it is burned instead of wood, in such countries as do not possess that fuel. The sublimation is performed in large round bottles of one foot and a half diameter, terminating in a neck of two inches in height; and they are filled to within four inches of the neck. The fire is kept up during three times twenty-four hours; the salt is sublimed to the upper part of these vessels, where it forms a mass of the same figure as the vessels themselves. Twenty

pounds of foot afford six pounds of sal ammoniac, according to Rudenskiold.

I was always of opinion that sal ammoniac might be extracted by treating the dung of the numerous animals which feed on saline plants in the plains of La Camargue and La Crau, in the same manner; and after having procured, with the greatest difficulty, two pounds of the foot, I extracted from it four ounces of sal ammoniac. I must observe, to save much trouble to those who may wish to follow this branch of commerce, that the dung produced during the summer, the spring, or the autumn, does not afford this salt. I did not know to what circumstance to attribute the versatility of my results, until I found that these animals do not eat saline vegetables, excepting at the time when fresh plants cannot be had; and that they are reduced to the necessity of having recourse to saline plants only during the three winter months. This observation appears to me to be a proof, that marine salt is decomposed in the first passages; and that the soda is modified to the state of ammoniac.

Sal ammoniac is continually sublimed through the apertures of volcanic mountains. Mr. Ferber found it; and Mr. Sage admitted its existence among volcanic products. It is found in
the

the phlogos of Puzoz, according to Messrs. Swab, Scheffer, &c.

It is found in the country of the Calmucs. Model analysed it.

It is also produced in the human body, and exhales by perspiration in malignant fevers. Mr. Model has proved this fact in his own person: for at the time of a violent sweat which terminated a malignant fever, he washed his hands in a solution of pot-ash, and observed that a prodigious quantity of alkali gas was disengaged.

Sal ammoniac crystallizes by evaporation in quadrangular prisms, terminated by short quadrangular pyramids. It is often obtained in rhombic crystals by sublimation. The concave face of the loaves of sal ammoniac in commerce is sometimes covered with these crystals.

This salt has a penetrating, acid, urinous taste. It possesses a degree of ductility which renders it flexible, and causes it to yield to a blow of the hammer. It does not change in the air; which circumstance renders it probable that our sal ammoniac is different from that mentioned by Elmiy and Agricola, as that attracted humidity. Three parts and a half of water dissolve one part of sal ammoniac, at sixty degrees of Fahrenheit's thermometer; a considerable degree of cold is produced by its solution.

One hundred parts of sal ammoniac contain

fifty-two parts acid, forty ammoniac, and eight water.

This salt is not at all decomposed by clay; nor by magnesia except with difficulty, and in part only; but it is completely decomposed by lime and fixed alkalis. The sulphuric and nitric acids disengage its acid.

This salt is used in dyeing, to bring out certain colours. It is mixed with aqua fortis, to increase its solvent power.

It is used in foldering; in which operation it possesses the double advantage of clearing the metallic surface, and preventing its oxidation.

C H A P. V.

Concerning the Nitro-muriatic Acid.

THE acid which we call Nitro-muriatic, is a combination of the nitric and muriatic acids.

Our predecessors distinguished it by the name of Aqua Regia, on account of its property of dissolving gold.

There are several known processes for making this mixed acid.

If two ounces of common salt be distilled with four of nitric acid, the acid which comes

over

over into the receiver will be good Nitro-muriatic acid.

This is the process of Mr. Baumé.

The nitrate of pot-ash may be decomposed by distilling two parts of muriatic acid from one of this salt: good aqua regia is the product of this operation; and the residue is a muriate of pot-ash, according to Mr. Cornette.

Boerhaave affirms that he obtained a good aqua regia, by distilling a mixture of two parts of nitre, three of sulphate of iron or martial vitriol, and five of common salt.

The simple distillation of nitre of the first boiling affords aqua regia; which is employed by the dyers in the solution of tin, for the composition of the scarlet dye. This aqua fortis is a true aqua regia; and it is by virtue of the mixture of acids that it dissolves tin; for if it consisted of the nitric acid in a state of too great purity, it would corrode and oxide the metal without dissolving it. The dyers then say that the aqua fortis precipitates the tin; and they correct the acid by dissolving sal ammoniac or common salt in it.

Four ounces of sal ammoniac in powder, dissolved gradually, and in the cold, in one pound of nitric acid, form an excellent aqua regia. An exsanguinated muriatic acid gas is disengaged

engaged for a long time; which it is imprudent to attempt to coerce, and which ought to be suffered to escape by convenient apertures.

Aqua regia is likewise formed by mixing together two parts of pure nitric acid and one of muriatic acid.

The very evident smell of oxygenated muriatic acid, which is disengaged in every process which can be adopted to form the acid at present in question; and the property which it possesses, equally with the oxygenated muriatic acid, of dissolving gold, have led certain chemists to infer that, in the mixture of these two acids, the muriatic acid seized the oxygen of the nitric, and assumed the character of oxygenated muriatic acid; so that the nitric acid was considered as answering no other purpose than that of oxygenating the muriatic. But this system is inconsistent; and though the virtues of the muriatic acid are modified by this mixture, and it is oxidized by the decomposition of a portion of the nitric acid; nevertheless the two acids still exist in the aqua regia; and I am convinced that the best made aqua regia, saturated with pot-ash, will afford the ordinary muriate, the oxygenated muriate, and the nitrate. It appears to me, that the powerful action of aqua regia depends simply on the union of the two acids;

one

one of which is exceedingly well calculated to oxide the metals, and the other dissolves the oxides or calces with the greatest avidity.

C H A P. VI.

Concerning the Acid of Borax.

THE acid of borax, more generally known by the name of Homberg's Sedative Salt, is almost always afforded by the decomposition of the borate of soda, or borax. But it has been found perfectly formed in certain places; and we have reason to hope that we shall speedily acquire more accurate information respecting its nature.

Mr. Hoefer, director of the Pharmacies of Tuscany, was the first who detected this acid salt in the waters of the lake Cherchiajo; near Monte-rotondo, in the inferior province of Siena: these waters are very hot, and they afforded him three ounces of the pure acid in one hundred and twenty pounds of the water. This same chemist having evaporated twelve thousand two hundred and eighty grains of the water of the lake of Castelnuovo, obtained one hundred and

and twenty grains. He presumes, moreover, that it might be found in the water of several other lakes, such as those of Lassa, Montecerbioni, &c.

Mr. Sage has deposited in the hands of the Royal Academy of Sciences some acid of borax, brought from the mines of Tuscany by Mr. Besson, who collected it himself.

Mr. Westrumb found sedative salt in the stone called Cubic Quartz of Lüneburg. He obtained it by decomposing this stone by the acids of sulphur, nitre, &c. The result of his analysis is the following:

Sedative salt	10
Calcareous earth	10
Magnesia	10
Clay and silex	10
Iron	—

This stone, according to the observations of Laffius, has the form of small cubical crystals, sometimes transparent, in other specimens milky, and affords sparks with the steel. The acid of borax is generally found combined with soda. It is from this combination that it is disengaged, and obtained either by sublimation or crystallization.

When it is proposed to obtain it by sublimation, three pounds of calcined sulphate of iron,

iron, and two ounces of borate of soda, are dissolved in three pounds of water. The solution is then filtered, and evaporated to a pellicle; after which the sublimation is performed in a cucurbit of glass with its head. The acid of borax attaches itself to the internal surface of the head, from which it may be swept by a feather.

Homburg obtained it by decomposing of borax with the sulphuric acid. This process succeeded with me wonderfully well. For this purpose I make use of a glass cucurbit with its head, which I place on a sand bath. I then pour upon the borax half its weight of sulphuric acid, and proceed to sublimation. The sublimed acid is of the most beautiful whiteness.

Stahl, and Lemery the younger, obtained the same acid by making use of the nitric and muriatic acids.

To extract the acid of borax by crystallization, the borax is dissolved in hot water, and an excess of sulphuric acid is poured in. A salt is deposited during the cooling on the side of the vessel, in the form of thin round plates, applied one upon the other. This salt, when dry, is very white, very light, and of a silvery appearance. It is the acid of borax.

We are indebted to Geoffroy for this process.

Baron

Baron has added two facts: the first, that the vegetable acids are equally capable of decomposing borax; and the second, that borax may be regenerated by combining the acid of borax with soda.

This acid may be purified by solution, filtration, and evaporation; but it must be observed, that a considerable part is volatilized with the water which flies off in the evaporation.

The acid of borax has a saline cool taste. It colours the tincture of turnsole, syrup of violets, &c. red.

One pound of boiling water dissolved not more than one hundred and eighty-three grains, according to Mr. De Morveau.

Alcohol dissolves it more easily; and the flame which this solution affords is of a beautiful green. This acid, when exposed to the fire, is reduced to a vitriform and transparent substance, instead of rising; which proves, as Rouelle has observed, that it is only sublimed by favour of the water, with which it forms a very volatile compound.

As most of the known acids decompose this acid, and exhibit it in the same form, it has been thought a justifiable conclusion that it exists ready formed in the borax. Mr. Baumé has even affirmed that he composed this acid by
leaving

leaving a mixture of grey clay, grease, and cows dung exposed to the air in a cellar. But Mr. Wiegley, after an unsuccessful labour of three years and a half, thinks himself authorised to give a formal negative to the French chemist.

Mr. Cadet has endeavoured to prove—
 1. That the acid of borax always retains a portion of the acid employed in the operation.
 2. That this same acid has still the mineral alkali for its basis.—Mr. De Morveau has, with his usual sagacity, discussed all the proofs brought forward by Mr. Cadet; he has shewn that none of them are conclusive, and that the acid of borax is entitled to retain its place among the chemical elements.

ARTICLE I.

Borate of Pot-ash

The acid of borax combined with pot-ash forms this salt. It may be obtained either by the direct combination of these two separate principles, or by decomposing borax by the addition of pot-ash.

This salt, which is yet little known, afforded Mr. Baumé small crystals.

The acids disengage it by seizing its alkaline base.

ARTI-

ARTICLE II.

Borate of Soda.

This combination forms Borax, properly so called.

It is brought to us from the Indies; and its origin is still unknown.

The article Borax may be consulted in *Bo-mare's Dictionary of Natural History*.

It does not appear that borax was known to the ancients. The *chrysolotta*, of which *Dioscorides* speaks, was nothing but an artificial solder composed, by the goldsmiths themselves, with the urine of children and rust of copper, which were beaten together in a mortar of the same metal.

The word Borax is found for the first time in the works of *Geber*. Every thing which has been written since that time concerning borax,

* The origin of borax is very well ascertained in two Papers, in the seventy-seventh volume of the *Philosophical Transactions*, Numbers xxviii, and xxix. It is dug up in a crystallized state from the bottoms of certain salt lakes in a mountainous, barren, volcanic district, about twenty-five days journey to the eastward of Lassa, the capital of the kingdom of Thibet. T.

is applicable to the substance which is at present known to us by that name.

Borax is found in commerce in three different states.—The first is brute borax, tincall, or chrysolocolla. It comes to us from Persia, and is enveloped and soiled by a greasy covering. The pieces of brute borax have almost all of them the form of a six-sided prism, slightly flattened, and terminated by a dihedral pyramid. The fracture of these crystals is brilliant, with a greenish cast. This kind of borax is very impure. It is pretended that borax is extracted from the lake of Neebal, in the kingdom of Grand Thibet. This lake is filled with water during the winter, which exhales in the summer, and when the waters are low, workmen enter, who detach the crystals from the muddy bottom, and put them into baskets.

The West Indies contain borax. It is to Mr. Anthony Carera, a physician established at Potosi, that we are indebted for this discovery. The mines of Riquintipa, and those in the neighbourhood of Escapa, afford this salt in abundance. The natives use it in the fusion of copper ores.

The second kind of borax known in commerce comes from China. It is purer than the
preced-

preceding, and has the form of small plates crystallized upon one of their surfaces, on which the rudiments of prisms may be perceived. This borax is mixed with a white powder, which appears to be of an argillaceous nature.

These several kinds of borax have been purified at Venice for a long time; and afterwards in Holland, but Messrs. Laguiller refine it at present in Paris: and this purified borax forms the third kind which is met with in commerce.

In order to purify borax, nothing more is necessary than to clear it of the unctuous substance which soils it, and impedes its solution.

Crude borax added to a solution of mineral alkali, is more completely dissolved, and may be obtained of considerable beauty by a first crystallization; but it retains the alkali made use of: and borax, purified in this manner, possesses a greater proportion of alkali than in its crude state.

The oily part of borax may be destroyed by calcination. By this treatment it becomes more soluble, and may in fact be purified in this way. But the method is attended with a considerable loss, and is not so advantageous as might be imagined.

The most simple method of purifying borax, consists in boiling it strongly, and for a long time.

time. This solution being filtrated, affords by evaporation crystals rather foul; which may be purified by a second operation similar to the foregoing. I have tried all these processes in the large way; and the latter appeared to me to be the most simple.

Purified borax is white, transparent, and has a somewhat greasy appearance in its fracture.

It crystallizes in hexahedral prisms, terminated by trihedral and sometimes hexahedral pyramids.

It has a styptic taste.

It converts syrup of violets to a green.

When borax is exposed to the fire, it swells up, the water of crystallization is dissipated in the form of vapour; and the salt then becomes converted into a porous, light, white, and opaque mass, commonly called Calcined Borax. If the fire be more strongly urged, it assumes a pasty appearance, and is at length fused into a transparent glass of a greenish yellow colour, soluble in water; and which loses its transparency by exposure to the air, in consequence of a white efflorescence that forms upon its surface.

This salt requires eighteen times its weight of water, at the temperature of sixty degrees of Fahrenheit's thermometer, to dissolve it. Boiling water dissolves one-sixth of its weight.

Barytes

Barytes and magnesia decompose borax. Lime-water precipitates the solution of this salt; and if quick-lime be boiled with borax, a salt of sparing solubility is formed, which is the borate of lime.

Borax is used as an excellent flux in domestic operations. It enters into the composition of reducing fluxes, and is of the greatest use in analyses by the blow-pipe. It may be applied with advantage in glass manufactories; for when the fusion turns out bad, a small quantity of borax re-establishes it. It is more especially used in foldering. It assists the fusion of the folder, causes it to flow, and keeps the surface of the metals in a soft or clean state, which facilitates the operation. It is scarcely of any use in medicine. Sedative salt alone is used by some physicians; and its name sufficiently indicates its application.

Borax has the inconvenience of swelling up, and requires the greatest attention on the part of the artist who uses it in delicate works, more especially when designs are formed with gold of different colours. It has been long a desideratum to substitute some composition in the room of borax, which might possess its advantages without its defects.

Mr. Georgi has published the following pro-

cess:—"Natron, mixed with marine salt and Glauber's salt, is to be dissolved in lime-water; and the crystals which separate by the cooling of the fluid may be set apart. The lixivium of natron is then to be evaporated; and this salt afterwards dissolved in milk. The evaporation affords scarcely one-eighth of the natron employed, and the residue may be applied to the same uses as borax."

Messrs. Struve and Exchaquet have proved that the phosphate of pot-ash, fused with a certain quantity of sulphate of lime, forms an excellent glais for soldering metals.—See the *Journal de Physique*, t. xxix. p. 78, 79.

ARTICLE III.

Borate of Ammoniac.

This salt is still little known. We are indebted to Mr. De Fourcroy for the following indications:—He dissolved the acid of borax in ammoniac, and obtained by evaporation a bed or plate of crystals connected together, whose surface exhibited polyhedral pyramids. This salt has a penetrating and urinous taste; it renders the syrup of violets green; gradually loses its crystalline form, and becomes of a

brown colour, by the contact of air. It appears to be of considerable solubility in water. Lime disengages the volatile alkali.

CONCERNING MINERAL WATERS*.

THE name of Mineral Water is given to any water whatever which is sufficiently loaded with foreign principles to produce an effect upon the human body, different from that which is produced by the waters commonly used for drink.

Men, doubtless, were not long in attending to the differences of waters. Our ancestors appear even to have been more strictly attentive than ourselves to procure wholesome drink. It was almost always the nature of the water which

* As mineral waters bear relation to every part of chemistry, their analyses may be indifferently placed at the end of any one of the parts. But as the nature of the principles they contain suppose an acquaintance with the products of the three kingdoms, it is more natural to reserve the article of the mineral waters for the conclusion of a course of chemistry. I have thought proper to change this order for no other reason, than because I foresaw that the third volume of this work would be of too large a size even without it.

determined their preference in the situation of towns, the choice of habitations, and consequently the union of citizens. The smell, the taste, and more especially the effects of waters upon the animal economy, have been thought sufficient, during a long time, to determine their nature. We may see, in the writings of Hippocrates, how much observation and genius are capable of performing in subjects of this nature. This great man, of whom it would afford but a very imperfect idea to consider him merely as the Father of Medicine, was so well acquainted with the influence of water upon the human body, that he affirms that the mere quality of their usual drink is capable of modifying and producing a difference between men, and he recommends to young physicians to attend more particularly to the nature of the waters their patients ought to use. We see that the Romans, who were frequently under the necessity of settling in parched climates, spared no exertions to procure wholesome water to their colonies. The famous aqueduct which carried the water of Uzès to Nîmes, is an unequivocal proof of this, and we still possess several mineral springs at which they formed colonies, for the advantage of the baths.

It was not till near the seventeenth century

that the application of chemical methods to the examination of waters was first made. We are indebted to the present revolution of chemistry for the degree of perfection to which this analysis has been carried.

The analysis of waters appears to me to be necessary, in order—

1. That we may not make use of any water for drink but such as is wholesome.
2. That we may become acquainted with those which possess medicinal virtues, and apply them to the uses to which they are suited.
3. To appropriate to the different works or manufactories that kind of water which is the best calculated for their respective purposes.
4. To correct impure waters, or such as are either impregnated with any noxious principle, or charged with any salt.
5. To imitate the known mineral waters, in all places and at all times.

The analysis of mineral waters is one of the most difficult problems of chemistry. In order to make a perfect analysis, it is necessary to be aware of all the distinctive characters of the substances which may be held in solution in any water. The operator must be acquainted with the means of separating from an almost insens-

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ble residue the different substances which compose it. He must be able to appreciate the nature and quantity of the products which are carried off by evaporation; and likewise to ascertain whether certain compounds are not formed by the operations of his analysis, while others may be decomposed.

The substances contained in waters are held either in suspension or in solution.

1. Those substances which are capable of being suspended in waters are, clay, silex in a state of division, calcareous earth, magnesia, &c.

Those which are soluble are, pure air, the carbonic acid, pure or compound alkalis, lime, magnesia, the sulphates, the muriates, the extractive matter of plants, hepatic gas, &c. The most ancient, the most general, and the most simple division of mineral waters, is that which distinguishes them into cold waters and hot or thermal waters, accordingly as their temperature is the same, or exceeds that of common water.

A division founded on the several qualities of these waters, will arrange them in four classes.

I. Acidulous or Gaseous Waters.—These are known by their penetrating taste; the facility with which they boil; the disengagement of bubbles

bubbles by simple agitation, or even by mere standing; the property of reddening the tincture of turnsole; the precipitating lime-water, &c.

They are either cold or hot. The first are those of Seltz, of Chateldon, of Vals, of Perols, &c. The second are those of Vichy, of Mont-d'or, of Chatelguyon, &c.

II. Saline waters, properly so called.—These are characterized by their saline taste, which is modified according to the nature of the salts they contain. The salts most generally found in waters are, the muriate of magnesia, the sulphates of soda, of lime, &c. Our waters of Balaruc, of Yeuset, &c. are of this nature.

III. Sulphureous Waters.—These waters have long been considered as holding sulphur in solution. Messrs. Venel and Monnet opposed this assertion. Bergmann has proved that most of these waters are merely impregnated with hepatic gas. It appears, however, that there are some which hold true liver of sulphur in solution, such as those of Bareges and of Cotteret; whereas the waters of Aix la Chapelle, Montmorency, &c. are of the nature of those mentioned by Bergmann. We may, with Mr. De Foureroy, call the first by the name of Hepatic Waters, and the latter by the name of Hepatized Waters.

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This class is known by the smell of rotten eggs which they emit.

IV. Martial Waters.—These have the property of exhibiting a blue colour by the solution of prussiate of lime: they have besides a very evident astringent taste. The iron is held in solution either by the carbonic or the sulphuric acid. In the first case the acid is either in excess, and the water has a penetrating subacid taste, as the waters of Bussang, Spa, Pyramont, Pougues, &c.: or the acid is not in excess, and consequently the waters are not acidulous; such are the waters of Forgès, Condé, Aumale, &c. Sometimes the iron is combined with the sulphuric acid, and the water holds in solution a true sulphate of iron. Mr. Opoix admits this salt in the waters of Provins; and those of Rougne near Alais are almost saturated with it. Mineral waters of this quality are frequently found in the vicinity of strata of pyrites. There are several near Amalou, and in the diocese of Uzes.

There are some waters which may be placed indiscriminately in several of the classes. Thus, for example, there are saline waters which may be confounded with gaseous waters, because air is constantly desengaged from them. The waters of Balaruc are of this kind.

We do not comprehend among mineral waters

waters those which suffer gas to escape through them, without communicating any characteristic property; such as the burning spring of Dauphiny, &c.

When the nature of any water is ascertained, its analysis may be proceeded upon by the union of chemical and physical means. I call those methods physical, which are used to ascertain certain properties of water without decomposing them. These methods are, for the most part, such as may be carried into effect at the spring itself. The appearance, the smell, and the taste afford indications by no means to be neglected.

The limpidity of any water indicates its purity, or at least the accurate solution of the foreign principles it may contain; an imperfect transparency denotes that foreign substances are suspended. Good water has no smell: the smell of rotten eggs denotes liver of sulphur, or hepatic gas; a subtle and penetrating smell is proper to acidulous waters; and a fetid smell characterizes stagnant waters.

The bitterness of waters in general depends on neutral salts. Lime, and the sulphates, give them an austere taste.

It is likewise of importance to ascertain the specific gravity of the water, which may be done either by means of the areometer, or by the

the comparison of its weight with that of an equal volume of distilled water.

The degree of heat must likewise be taken by means of a good mercurial thermometer. Thermometers made with spirits of wine ought to be rejected ; because the dilatation, after the thirty-second degree of Reaumur, is extreme, and no longer corresponds with the temperature of the water. It is interesting to calculate the time which the water requires to become cool, in comparison with distilled water raised to the same degree of temperature. Notice must likewise be taken whether any substance exhales, or is precipitated by the cooling.

The observer ought likewise to enquire whether rains, dry seasons, or other variations of the atmosphere, have any influence on the temperature or quantity of water of the spring. If these causes act upon the spring, its virtue cannot but vary exceedingly. This is the cause why certain mineral waters are more highly charged with their principles in one year than in another ; and hence also it arises that certain waters produce wonderful effects in some years, though in other seasons their effects are trifling. The celebrated De Haen, who analysed for several successive years all the waters in the neighbourhood of Vienna, never found them to contain the same principles

principles in the same proportion. It would therefore be an interesting circumstance, if, at the time of taking up or bottling of these waters, a skilful physician were to analyse them; and publish the result.

After these preliminary examinations have been made at the spring, further experiments must be made according to the methods of chemistry. These experiments ought to be performed at the spring itself: but if this cannot be done, new bottles may be filled with the water; and, after closing them very accurately, they may be carried to the laboratory of the chemist, who must proceed to examine them by re-agents, and by the method of analysis.

I. The substances contained in water are decomposed by means of re-agents; and the new combinations or precipitates which are formed; immediately point out the nature of the principles contained in the waters. The most efficacious and the only necessary re-agents are the following:

1. Tincture of turnsole becomes red by its mixture with acidulous waters.
2. Prussiate of lime, and that of ferruginous pot-ash not saturated, precipitate the iron contained in a mineral water of a blue colour.
3. The very concentrated sulphuric acid de-

composes most neutral salts; and forms with their bases salts very well known, and easily distinguished.

4. The oxalic acid, or acid of fugar, disengages lime from all its combinations, and forms with it an insoluble salt.

The oxalate of ammoniac produces a more speedy effect; for, by adding a few crystals of this salt to water charged with any calcareous salt, an insoluble precipitate is instantly formed.

5. Ammoniac or volatile alkali affords a beautiful blue colour with the solutions of copper. When this alkali is very pure, it does not precipitate the calcareous salt, but decomposes the magnesian only. In order to have it in a highly caustic state, a syphon may be plunged in the mineral water, and ammoniacal gas or alkaline air passed through it. The water ought to be kept from the contact of the atmosphere, which otherwise might occasion a precipitation by virtue of its carbonic acid.

6. Lime water precipitates magnesia; and it likewise precipitates the iron from a solution of sulphate of iron.

7. The muriate of barytes detects the smallest particle of sulphuric salts, by the regeneration of ponderous spar, which is insoluble, and falls down.

8. Alco-

8. Alcohol is a good re-agent, on account of its affinity with water.

The nitrates of silver and of mercury may likewise be employed to decompose sulphuric or muriatic salts.

II. These re-agents, indeed, point out the nature of the substances contained in any water; but they do not exhibit their accurate proportions. For this purpose we are obliged to have recourse to other means.

There are two things to be considered in the analysis of any water—1. The volatile principles. 2. The fixed principles.

1. The volatile principles are carbonic acid gas and hepatic gas. The proportion of carbonic acid may be ascertained by various processes. The first, which has been used by Mr. Venel, consists in half filling a bottle with the gaseous water intended to be analysed. A bladder is then to be tied upon the neck of the bottle, and the water agitated. The air which is disengaged inflates the bladder; and by that indication an estimate may be made of its quantity. This process is not accurate; because agitation is not sufficient to disengage the whole of the carbonic acid. Neither is the evaporation of the water in the pneumato-chemical apparatus much more exact; because the water

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ter which rises with the air combines again with it, and the gaseous product consists only of a part of the gas contained in the water. The precipitation by lime-water appears to me to be the most accurate process. Lime-water is poured into a determinate quantity of the water, until it ceases to cause any precipitate. This precipitate being very accurately weighed, $\frac{1}{11}$ parts of the whole must be deducted for the proportion in which water and earth enter into it; and the remainder is the acid contained in this carbonate of lime.

Hepatic gas may be precipitated by the very concentrated nitric acid, according to the experiments of Bergmann.

The oxygenated muriatic acid has been proposed by Scheele; and Mr. De Fourcroy has pointed out the sulphureous acid, the oxides of lead, and other re-agents, to precipitate the small quantity of sulphur held in solution in hepatic gas.

2. Evaporation is commonly used to ascertain the nature of the fixed principles contained in any mineral water. Vessels of earth or porcelain are the only kind suitable to this purpose.

The evaporation must be moderate; for strong ebullition volatilizes some substances, and decomposes others. In proportion as the
evaporation

evaporation proceeds, precipitates are afforded, which Mr. Boulduc proposes to take out as they are formed. The celebrated Bergmann advises evaporation to dryness, and to analyse the residue in the following manner:

1. This residue must be put into a small phial, and strongly agitated with alcohol; after which the fluid must be filtrated.
2. Upon the residue pour eight times its weight of cold distilled water; agitate this, and filter the fluid, after standing several hours.
3. Lastly, the residue must be boiled for a quarter of an hour in five or six hundred parts of distilled water, which fluid must be separated by filtration.
4. The residue, which is neither soluble in water nor in alcohol, must then be moistened, and exposed for several days to the sun: by this treatment, the iron which it may contain, rusts. It must then be digested in distilled vinegar, which dissolves lime and magnesia; and this solution, evaporated to dryness, affords either an earthy salt in filaments which are not deliquescent, or a deliquescent salt; which last has magnesia for its base. The insoluble residue contains iron and clay, which are to be dissolved in the muriatic acid. The iron is first to be precipitated.

precipitated by the prussiate of lime; and afterwards the clay by another alkali.

The salts which the alcohol has dissolved, are the muriates of magnesia and of lime. They are easily known by decomposing them by the sulphuric acid.

With respect to the salts dissolved in the cold water, they must be slowly crystallized; and their form, and other obvious qualities, will shew what they are.

The solution by boiling water contains nothing but sulphate of lime.

When the analysis of any water has been well made, the synthesis becomes easy; and the composition or perfect imitation of mineral waters is no longer a problem insoluble to chemists. What, in fact, is a mineral water? It is rain water, which, filtering through the mountains, becomes impregnated with the various soluble principles it meets with. Why, therefore, when once we know the nature of these principles, can it not be possible to dissolve them in common water, and to do that which nature itself does? Nature is inimitable only in its vital operations; we may imitate its effects perfectly in all other processes: we may even do better; for we can at pleasure vary the temperature and the proportions of the constituent

288 *Examination of Mineral Waters.*

ent parts. The machine of Nooth, improved by Parker, may be made use of to compose any gaseous mineral water, whether acidulous or hepatic; and nothing is more easy than to imitate such waters as contain only fixed principles.

THE END OF THE FIRST VOLUME.









